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THE CAPACITY OF CORK FOREST FOR THE RETROFITTING OF RESIDENTIAL BUILDING IN BARCELONA

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(Article begins on next page)



*Department of Science
for Nature and
Environmental
Resources of the
University of Sassari*



*Forestry and Wood
Research Centre of the
Italian Council for
Agricultural Research and
Economics*



ISE
Istituto per lo Studio
degli Ecosistemi

*Institute of Ecosystem Study of the
National Research Council,
organization unit of Sassari*



INTERNATIONAL CONGRESS ON CORK OAK TREES AND WOODLANDS

Conservation, Management, Products
and Challenges for the Future



3° National Congress of Cork

Sassari, May 25 – 26 2017

SPONSORSHIP



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Tipiditappi

*Sughero d'albero fatto a pezzetti,
tipi di tappi , quelli che vuoi.
Tagliali lunghi, tagliali stretti,
tipi di tappi, fatti da noi.
Taglialo bene, taglialo tondo,
tipi di tappi, quanti ne vuoi.
Tappi di sughero per tutto il mondo,
tipi di tappi fatti da noi.*
(Cecchi-Tognolini, Filastrocche e Canzoni)

Dettori S., Fligheddu M.R., Cillara M. Editors

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WELCOME

The Congress is intended as a forum for sharing Mediterranean experiences in the cork industry: from the conservation and sustainable management of cork forests to the aspects of industrial processes and alternative uses to cork stopper production.

The Congress is held in Sardinia, an island in the centre of the Western Mediterranean, where many rural landscapes are characterised by cork trees, which thus have environmental and economic value, and, hence also social value.

Sardinia is home to approximately 80% of Italy's cork oak forests. The application of Regulation (EEC) No 2080/92 instituting a Community aid scheme for forestry measures in agriculture and of the following. Regional implementing regulation have seen a marked preference by farmers for cork oak over other tree species: thus about 10,000 ha of cork stands have been planted, in addition to the existing 83,000 ha of specialised cork stands. The Region's production, which is 5% of global output, covers approximately 50% of the demand from the local processing industry; the rest is covered by regular imports from the Iberian Peninsula, North Africa and nearby Corsica.

The presence of a dynamic industry, with processing facilities concentrated in upper Gallura, increases the importance of the supply chain. There are also agro-forestry systems based on the cork oak (wooded pastures similar to the Iberians *montados*) where the soil is often cultivated with fall-winter grasses for dairy sheep.

The Region's main sheep's milk product is hard salty cheese (*pecorino romano*) and fluctuations in the prices of sheep's milk and natural cork determine the degree of pressure exerted by entrepreneurs on the forests' structure.

Thus, Sardinia constitutes an interesting case study because it features:

- Vast forests of cork oaks owned by regional and/or municipal public authorities, managed with sustainable and multifunctional systems, with high-growing trees and certification of the production process
- Privately-owned land with limited shrub vegetation to improve cork productivity and control defects caused by excessive humidity
- Agro-forestry systems (with beef cattle in Gallura and dairy sheep in Central Sardinia) with high natural and cultural value (HNV)
- Large processing industries (Gallura) and small and medium-sized processing enterprises spread across Central-northern Sardinia.

The two-day event will focus on the exchange of experiences between the local research and industry players and international players, and will provide an update on rural development policies.

It will also provide an opportunity to discuss the guidelines contained in the National Cork Plan currently being drafted on the initiative of the Ministry of Agricultural, Food and Forestry Policies, addressing one of the themes of the First National Conference on Cork held in Sassari in May 1934.



INTRODUCTION

The *Department of Science for Nature and Environmental Resources* of the University of Sassari, the *Forestry and Wood Research Centre* of the Italian Council for Agricultural Research and Economics and the *Institute of Ecosystem Study* of the National Research Council, organization unit of Sassari, are pleased to welcome you to the “International Congress on Cork Oak Trees and Woodlands: conservation, management, products and challenges for the future”, coinciding with the 3° National Congress of Cork. The event is part of the activities of the regional research project «Multifunctional role of Cork Oak Forests»

Plenary lectures, oral and poster presentations will concentrate on the following themes:

- *Session 1* Ecology, ecophysiology, health and genetic resources
- *Session 2* Forest monitoring and management, land and forest planning
- *Session 3* Multifunctionality of cork oak systems, biodiversity, climate change mitigation and landscape/ecosystem services
- *Session 4* History, economics and policy, social perception and communication, certification
- *Session 5* Cork supply chain technology, supply chain arrangements, markets and trade foresight, product and process innovation.

On the morning of the first Congress day, invited speakers will open the event during a plenary opening session with their keynote lectures.

The simultaneous translation service (English-Italian and vice-versa) will be provided at the main hall.

The program includes a permanent exhibition of the posters and is supplemented by an extensive post-congress tour for the weekend.

COMMITTEES

Scientific Committee

Sandro Dettori - *Dip. di Scienze della Natura e del Territorio, Università di Sassari, President*
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Marcello Verdinelli - *ISE, CNR*

SHORT PROGRAM

CONGRESS ORGANIZATION MAP				
		[Location]		
		[A]	[B]	[C]
THURSDAY May 25	09:00	Keynote		
	11:15	Poster exhibition		
	11:45	Keynote (cont.)		
	13:30	Working lunch		
	15:00	Session 1	Session 2	
	18:00			
FRIDAY May 26	09:00	Session 1 (cont.)	Session 4	Session 3
	10:00		Session 5	
	11:00	Poster exhibition		
	11:45	Session 1 (cont.)	Session 5 (cont.)	Session 3 (cont.)
	13:30	Working lunch		
Locations	[A]	Aula Magna, piazza Università		
	[B]	Fondazione Sardegna conference room, via Carlo Alberto, 7		
	[C]	Biblioteca Universitaria di Sassari (MiBACT, piazza Fiume)		
Sessions	1	Ecology, ecophysiology, health and genetic resources		
	2	Forest monitoring and management, land and forest planning		
	3	Multifunctionality of cork oak systems, biodiversity, climate change mitigation and landscape/ecosystem services		
	4	History, economics and policy, social perception and communication, certification		
	5	Cork supply chain technology, supply chain arrangements, markets and trade foresight, product and process innovation		

PROGRAM

THURSDAY, May 25, Aula Magna Università

08.30 **Registration**

09.00 **Opening Ceremony**

Chairman: **Sandro Dettori**

Greetings of the authorities and personalities. Speakers include:

Magnifico Rettore prof. **Massimo Carpinelli**

Sindaco di Sassari Dr. **Nicola Sanna**

Assessore dell'Agricoltura e Riforma Agro-Pastorale On.le **Pierluigi Caria**

Assessore della Difesa dell'Ambiente RAS prof. **Donatella Spano**

Direttore Generale CFVA Comandante Dr. **Gavino Diana**

Amministratore Unico Agenzia Fo.Re.S.T.A.S. prof. **Giuseppe Pulina**

Presidente Associazione Industriali Nord Sardegna Dr. **Pierluigi Pinna**

Presidente CCIAA di Sassari Dr. **Gavino Sini**

Presidente Accademia Italiana di Scienze Forestali prof. **Orazio Ciancio**

Presidente Società It. Selvicoltura Ecologia For. prof. **Marco Marchetti**



10.00-13.30 Keynote speeches (each followed by a brief discussion)

Chairman: Sandro Dettori		
10.00	Inazio Martinez de Arano , European Forest Institute - EFI	Moving towards a circular Bioeconomy: the role of forests
10.25	Giuseppe Pignatti , Centro di ricerca per la Selvicoltura del Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria	Towards a new National Cork Plan for Italy, between critical issues and new challenges
10.50	Maria Carolina Varela , Senior Forestry Researcher, retired from Instituto Nacional de Investigação Agrária e Veterinária, Oeiras Portugal	From genetic improvement to global change: what advantages and threats for the production, adaptation and evolution of cork oak?
11.15	<i>Coffee break and Poster exhibition</i>	
Chairman: Piermaria Corona		
11.45	Cristina Silva Pereira , Applied and Environmental Mycology Laboratory, Instituto de Tecnologia Química e Biológica, Universidade NOVA de Lisboa	A three-act play: pentachlorophenol threats to the cork oak forest soils mycobiome
12.10	Massimo Faccoli , Dipartimento di Agronomia Animali Alimenti Risorse Naturali e Ambiente, Università di Padova	Climate change and wood-boring beetles: a new challenge for the forest protection
12.35	Gösta Eriksson , Department of Plant Biology, Swedish University of Agricultural Sciences, Uppsala Sweden	EUFORGEN Technical bulletin on genetic conservation and management of <i>Quercus suber</i>
13.00	General discussion	
13.30	Working lunch	

A simultaneous translation service is available: English - Italian and vice versa

THURSDAY, May 25 afternoon, Aula Magna Università

15.15-17.30 Session 1 *Ecology, ecophysiology, health and genetic resources*

Chairman: Giuseppe Scarascia-Mugnozza		
15.15	Boher P., Serra O., Soler M., Hoede C., Noirot C., Paiva J., Molinas M., <u>Figueras M.</u>	What genes make phellem a cork?
15.30	<u>Fernández-Piñán S.</u> , Boher P., Soler M., Molinas M., Figueras M., Serra O.	Cork seasonal growth: a transcriptomic overview
15.45	López de Heredia U., <u>Soto A.</u>	Simulation analysis suggest <i>Quercus suber</i> x <i>Quercus ilex</i> hybridization could be underestimated
16.00	López de Heredia U., Sánchez H., <u>Soto A.</u>	Molecular evidence of bidirectional introgression between <i>Quercus suber</i> and <i>Quercus ilex</i>
16.15	<u>López de Heredia U.</u> , Duro-García M. J., Soto A.	Leaf morphology of progenies of <i>Q. suber</i> , <i>Q. ilex</i> , and their hybrids using multivariate and geometric morphometric analysis
16.30	<u>de Dato G.</u> , Teani A., Mattioni C., Monteverdi M.C., Ducci F.	Genetic structure of <i>Quercus suber</i> populations in Sardinia for their exploitation as seed stands
16.45	<u>Maltoni S.</u> , Casula A., Patteri G., Cinus G., Cubeddu G., Monteverdi M.C., de Dato G., Ducci F.	The certification of cork oak reproductive material in Sardinia following the 1999/105/CE directive
17.00	General discussion	

THURSDAY, May 25 afternoon, Fondazione di Sardegna conference room

15.00-18.00 Session 2 *Forest monitoring and management, land and forest planning*

Chairman: Inazio Martinez de Arano		
15.00	Piredda I., Campus S.F., Ganga A., Lovreglio R., <u>Scotti R.</u>	Land planning for forest management, the Arci Grighine (Sardinia) study case
15.15	<u>Faias SP.</u> , Paulo JA., Tomé M.	Tree diameter growth model for cork oak stands in Portugal
15.30	<u>Lambri M.</u> , Galli R., Monti M., Torchio F., De Faveri D.M.	Micro-granulate cork stoppers: study on overall and specific migration
15.45	<u>Faias SP.</u> , Paulo JA., Tomé M.	Competition pattern in young cork oak stands
16.00	Deplano G., Ruiu M., <u>Schirru M.</u>	Land Use Change in a silvopastoral cork oak savanna of central Sardinia
16.15	<u>Silva J.M.N.</u> , Cerasoli S., Soares C., Gómez-Candón D.	Monitoring cork oak open woodlands with proximal remote sensing
16.45	Ferrara R., Ventura A., Arca A., Masia P., Virdis S., <u>Pellizzaro G.</u>	Using terrestrial LIDAR for monitoring canopy structure in cork oak trees
17.00	<u>Salis M.</u> , Arca B., Alcasena-Urdiroz F., Massaiu A., Bacciu V., Diana G., Bosseur F., Caramelle P., Santoni P.A., Molina Terren D., Vega-Garcia C., Dettori S., Spano D.	Recent dynamics of forest fires in <i>Quercus suber</i> stands in Sardinia, Corsica and Catalonia
17.15	Arteaga C., <u>Molina-Terrén D.M.</u> , Nebot E.	Towards an integrative fire management in <i>Quercus suber</i> L. forests in NE Spain
17.30	General discussion	

FRIDAY, May 26, Aula Magna Università

09.15-13.00 Session 1 *Ecology, ecophysiology, health and genetic resources*

Chairman: Cristina Silva Pereira		
09.15	Varela MC.	Biennial fruiting in cork oak
09.30	Monteverdi M.C., de Dato G., Mulas M., Arcadu M., Germani A., Proietti R., Addis M., Maltoni S., Casula A., <u>Ducci F.</u>	Identification of cork characters for phenotypic selection
09.45	<u>Varela M.C.</u> , Sampaio T., Filigheddu M.R., Zucca G.M., Patrício M.S., Almeida M.H., Ramirez-Valiente J.A., Aranda I., Tessier C., Ladier J., Dettori S.	Provenance behaviour in the Cork-Oak International Network Trials FAIR 202
10.00	<u>Proietti R.</u> , de Dato G., Dettori S., Marchi M., Monteverdi M.C., Zucca M., Ducci F.	One year monitoring of bud break phenology in a FAIR 202 (Grighine, Sardinia) international field test
10.15	<u>Lobo-do-Vale R.</u> , Kurz-Besson C.B., Nogueira C., Chaves M.M., Pereira J.S.	Physiological variability of cork oak trees in response to increasingly dry years
10.30	<u>D'Acqui L.P.</u> , Verdinelli M., Cossu C.S., Mannu R., Bonetti A.	Photoacoustic spectroscopy for estimating nutritional indices in lepidopteran defoliators
10.45	<u>Belhoucine-Guezouli L.</u> , Dehane B., Bouhraoua R.T., Barka F.	Epidemiological characterization of <i>Platypus cylindrus</i> (Col., Curculionidae, Platypodinae) attacks in a cork oak stand of M'Sila in the North-West of Algeria
11.00	<i>Coffee break and Poster exhibition</i>	
Chairman: Marcello Verdinelli		
12.15	<u>Selvi F.</u> , Carrari E., Coppi A.	Impact of pine invasion on the taxonomic and phylogenetic diversity of Tyrrhenian cork oak forests
12.30	General Discussion	
13.15	Working lunch	

FRIDAY, May 26, Biblioteca Universitaria di Sassari (MiBACT)

09.15-13.00 Session 3 *Multifunctionality of cork oak systems, biodiversity, climate change mitigation and landscape/ecosystem services*

Chairman: Marco Marchetti		
09.15	<u>Potes J.</u>	Mediterranean forest: the inevitability of the multifunctionality
09.30	Sansone D., Paoli G., Bidini C., Monteverdi M.C., <u>Pelleri F.</u>	Mixed tree farming plantation with cork oak in Tuscany Grosseto Province
09.45	<u>Monteverdi M.C.</u> , Lauteri M., de Dato G., Germani A., Proietti R., Mulas M., Arcadu M., Maltoni S., Casula A., Ducci F.	Climate change influences on annual cork growth and quality
10.00	<u>Leites L.</u> , Curtze A., Johnson Q., Onofrio L., Smith G., Campus S., Cappai C., Seddaiu G.	Biomass and allometry of cork oak trees growing under different land uses in silvo-pastoral ecosystems
10.15	<u>Pungetti G.</u> , Filigheddu M.R., Deplano G., Muru D., Dettori S.	Cork oaks in the rural landscape of Sardinia
10.30	<u>Puletti N.</u> , Schirru M., Dettori S., Corona P., Quatrini V.	Modelling goods and services from cork oak forests
10.45	<u>Crous-Duran J.</u> , Paulo J.A., Graves A.R., Tomé M., Palma J.H.N.	Carbon balance estimation in cork oak woodlands compared to land use alternatives
11.00	General Discussion	
11.15	<i>Coffee break and Poster exhibition (Aula Magna Università)</i>	

FRIDAY, May 26, Fondazione di Sardegna conference room

09.15-10.30 Session 4 *History, economics and policy, social perception and communication, certification*

Chairman: Pietro Pulina		
09.15	<u>Tsvetkov I.</u>	A retrospection of cork oak (<i>Q. suber</i> L.) cultivation in Bulgaria
09.30	Dalla Vecchia I., <u>Pettenella D.</u>	Cork oak certification in the Mediterranean Basin: state of the art and market trends
09.45	<u>Brunori A.</u> , Dini F., Noriega A.B., Salazar P.	PEFC certification, sustainable cork production with marketing appeal
10.00	General discussion	
10.30	<i>Coffee break</i>	

11.15-13.00 Session 5 *Cork supply chain technology, supply chain arrangements, markets and trade foresight, product and process innovation*

Chairman: Margarida Tomè		
11.15	<u>Tomé M.</u> , Firmino P.N., Faias S.P., Paulo J.A.	Innovative methodology to include weather effects in a system of equations to predict the evolution of individual tree mature cork caliber over time
11.30	<u>Palma J.H.N.</u> , Paulo J.A., Tomé M.	WebCorky – an online decision support tool to decide when stand debarking should occur
11.45	<u>Pérez-Terrazas D.</u> , González-Adrados J.R., Sánchez-González M.	Feasibility study of Near Infrared Spectroscopy to detect yellow stain on cork granulate
12.00	García-Pérez S., Sierra-Pérez J., Boschmonart-Rives J., <u>Blanc S.</u>	The capacity of cork forest for the retrofitting of residential building in Barcelona
12.15	Sierra-Pérez J., <u>Blanc S.</u> , Demertzi M., Dias A.C., Boschmonart-Rives J., Gabarrell X.	Life Cycle Assessment of the use of natural materials as thermal insulation in buildings. The case of the white agglomerated and expanded cork boards
12.30	General Discussion	
13.15	Working lunch	
	Aula Magna Università	

Aula Magna Università

POSTER

Session 1 *Ecology, ecophysiology, health and genetic resources*

<u>Belhoucine-Guezouli L.</u> , Dehane B., Bouhraoua R.T., Smahi H., Barka F., Tefiani C.	Characterization and pathogenicity of <i>Geosmithia longdonii</i> associated with <i>Platypus cylindrus</i> (Col., Curculionidae, platypodinae) on cork oak in Algeria
<u>Habbachi W.</u> , Habbachi S., Ouakid M.L., Farine J.P.	Biodiversity of stands cockroaches in oak forests of Algerian Northeast
<u>Mannu R.</u> , Pilia O., Fadda M.L., Verdinelli M.	Assessing the response of ground-dwelling beetles communities to different land-uses in Mediterranean cork oak systems
<u>Mundet R.</u> , <u>Rovira J.</u> , Tusell J.M.	Biological control of <i>Coraebus undatus</i> to foster sustainable forest management of cork oak forests in Catalonia
Pasta S., <u>La Mantia T.</u> , Giaimo A., Pizzurro G.M., Scalenghe R.	The ecology of some cork-oak (<i>Quercus suber</i> L.) stands in NW Sicily

Session 2 *Forest monitoring and management, land and forest planning*

<u>Campus S.F.</u> , Piredda I., Ganga A., Murgia I., Scotti R.	Implementing row sampling for inventory in local planning of young cork oak plantations
<u>Cutini A.</u> , Fabbio G.	Shaping future forestry for sustainable coppice forests in Southern Europe
<u>Godinho Ferreira P.</u> , Santos L., Rodrigues A., Varela C.	Germination behaviour of large and small cork-oak seeds under different treatments
<u>Tsvetkov I.</u> , Zafirov N., Mirchev St.	Dendrochronological analysis of cork oak (<i>Q. suber</i> L.) adaptation in Southwestern Bulgaria

Session 3 Multifunctionality of cork oak systems, biodiversity, climate change mitigation and landscape/ecosystem services

<u>Martins C.</u> , Varela A., Núñez Ó., Moyano E., Silva Pereira C.S.	Modelling how pentachlorophenol pollution affects fungal biodiversity in cork oak forest soils
<u>Muru D.</u> , Deplano G., Filigheddu M.R., Dettori S.	Local landscape dynamics in a traditional cork-oak agro-forest farm (Sardinia)
<u>Pignatti G.</u>	Tree species richness in Italian cork oak forests
<u>Varela A.</u> , Martins C., Núñez Ó., Silva Pereira C.S.	Fungal communities act as buffer against the disturbance caused by pentachlorophenol in cork oak soil

Session 4 History, economics and policy, social perception and communication, certification

<u>Chiavetta U.</u> , Cutini A., Casula A., Maltoni S., Dettori S., Corona P.	Cork oak management sustainability: indicators for a certification prototype
<u>Deplano G.</u> , Filigheddu M.R., Zucca G.M., Cillara M., Dettori S.	Results of cork oak afforestation carried out under EEC 2080/92 Regulation in Gallura (Sardinia)
La Mela Veca D.S., Maetzke F., Badalamenti E., Sala G., Sferlazza S., <u>La Mantia T.</u>	The cork oak forests management in Sicily: current situation and potentiality
<u>Lai L.</u> , Filigheddu M.R., Dettori S.	The use of cork in antiquity: some archaeological data in Sardinia
<u>Schirru M.</u> , Dettori S.	Environmental characterization and cork oak presence by toponyms in Sardinia: an ethnoecological approach

Session 5 *Cork supply chain technology, supply chain arrangements, markets and trade foresight, product and process innovation*

<u>Tomé M.</u> , Paulo JA., Palma JHN., Firmino PN., Faias SP.	The SUBER Model, now with added options: simulating different silvicultural systems and associated products and services
<u>Urgeghe PP.</u> , Zucca G.M., Filigheddu M.R., Usai A., Motroni A., Canu S., Dettori S.	Monitoring raw cork TCA content in Sardinian woodlands
Zucca G.M., Fadda A., Addis M., Pinna G., <u>Mulas M.</u>	Monitoring of TCA concentration in stoppers obtained by cork oak from different Sardinian areas



ABSTRACTS

KEYNOTE SPEECHES



MOVING TOWARDS A CIRCULAR BIOECONOMY: THE ROLE OF FORESTS

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The pace of global change has dramatically changed since the 1950s to reach a level where human activities have become an environmental force that rivals natural processes. The population has more than doubled and economic activity has increased x10. International trade, capital and information flows have rapidly expanded, leading to highly globalised economies. The pressure on natural resources has greatly increased. Half of the world surface is domesticated. Water use and water resources regulation has increased six fold in the same period and is approaching planetary limits, as some 70 percent of the world's freshwater resource is now used for agriculture. Today, manufactured nitrogen for fertilizers exceeds terrestrial natural production of reactive nitrogen. Those are needed to produce enough food to sustain a population of seven billion people. The atmospheric concentration of CO₂ rose from 58ppm in 1950 to 369 ppm in 2000. Sociological and cultural changes are also deep and fast. This *global acceleration* has been based in the increased use of non-renewable materials and, remarkably, fossil fuels that have been extensively used for energy and a panoply of material uses, from plastics to textiles and carbon fibres... and there is more to come. In the last decades, a change of gear is taking place as developing countries are rapidly increasing their share in the global economy and in the consumption of natural resources.

Although the *great acceleration* has greatly improve livelihoods and wellbeing for millions of people it has also produced the biggest externalities ever recorded, jeopardizing those same societal achievements. These are: Climate change, hyper accumulation of waste and mass extinction. There is a clear need to re-think and re-engineer current production and consumption patterns and the relation between society, nature and earths life supporting systems.

There is a need to decarbonise the economy moving to renewable energies, where biomass is playing a relevant role. It is also necessary to decouple economic growth and resource consumption, reducing material use through resource efficiency, utilisation of waste as input for new processes, reusing and recycling products and, critically important, replacing non-renewable materials with bio based renewable products. Without neglecting the need to *degrowth* gross consumption levels, the circular bio-based economy emerges as a most relevant paradigm. It means reverting to green energy and biobased product to replace non-renewable and carbon intensive fossil fuel feedstocks and materials, reducing waste, carbon and overall ecological footprint of human activities while supporting competitiveness, health and wellbeing in a globalised world. In such a paradigm, forests and forestry have a critical role to play, for several

reasons: 1) forests represent over 40% European land area conforming a fabulous green infrastructure producing multiple ecosystem services 2) Mature and new technologies can transform lignocellulosic materials into virtually anything, from biofuels to engineered wood products, textiles, advance bioproducts... etc. 3) the forest based sector is already an existing technological and economy reality that employs over 1.5 million people and that can potentially lead a transformation in the way we use biobased resources, 4) globalisation and development of emerging economies is putting increased pressures on traditional forest based industries to re-invent themselves moving increasingly away from commodities into *new* high added value products and services and, finally 5) there is a political and societal momentum pushing towards low-carbon and circular economy that is shaping consumer behaviour in both the public and private spheres.

It must be acknowledged that the role of forest can widely vary across regions and that the bioeconomy is far from being *business as usual* and. This presentation explains why and presents the key building blocks for a forest based circular economy, specifically focusing on the role of Mediterranean forests.

Keywords: global acceleration, great acceleration, climate change, degrowth.

TOWARDS A NEW NATIONAL CORK PLAN FOR ITALY, BETWEEN CRITICAL ISSUES AND NEW CHALLENGES

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Cork oak distribution in Italy is restricted to the Tyrrhenian regions (Liguria, Tuscany, Sardinia, Latium, Calabria, Campania, Sicily), and to Apulia. The 2005 National Forest Inventory survey estimated a total cork oak forest surface of 168,602 ha, more than 80% of which in Sardinia. In this region, the cork oak forms pure stands (i.e. with more than 25% of forest cover) on 80,489 ha, but also acts as a tree component in pastures or crops (with 5-25% forest cover) on 57,934 ha, and cork oak is present as single trees in other broadleaved woods. The typical cork oak landscape is favoured by optimal environmental conditions and by human interventions, or, most probably, by both factors. For example, in Alta Gallura (NE-Sardinia), cork oak woodlands find the best socio-ecological conditions: they are still linked to agroforestry systems (cattle breeding), cork production involves qualified local skills and cork processing into high value products (stoppers) is carried out by local industry.

More recently, traditional cork oak landscapes have been threatened by environmental disturbances (e.g. increased fire risk, insect damage, and water stress), land use and socio-economic changes and intensive woodland management. In Sardinia, the transformation of pure cork oak systems into agro-forestry systems with low tree cover (pastures, arable land or shrub vegetation) following an intensification of agricultural and livestock activities, is related to cork price declining trend and changes in the sheep milk sector, reducing the ecosystem resilience. Even so, in recent decades the national raw cork production has been decreasing: from the highest levels of more than 15.000 tons per year (TPY) before 1980 to a current production only slightly exceeding 6.000 TPY, vs. an annual world production of about 200,000 TPY. The local, small-scale industry (mainly concentrated in the so-called “Gallura cork district”) has been shrinking, while raw cork exports have increased over the last few years together with decreasing imports. Only bigger companies are able to meet the challenges of globalization by expanding their markets with targeted commercial strategies.

Conservation of the unique cork oak habitat (both as sparse forest with a well-developed shrub and herbaceous layer, and as semi-natural systems maintained

by livestock breeding), sustainable cork utilization, solid ties with the wine industry, appropriate legislation oriented towards rural development and research into innovative cork products are some of the main key-points discussed recently in the framework of the National Cork Plan update. We emphasize here the most relevant topics, which have emerged in the discussion between representatives of research institutions and cork oak stakeholders, coordinated by the Ministry of Agricultural, Food and Forestry Policies.

The Italian cork oak system, like Iberian *montado* and *dehesa*, needs to find an equilibrium between opposing driving forces in order to maintain its ecological and socio-economic values. Despite the temptation to manage cork oak systems as simplified “cork oak plantations” characterized by low biodiversity and resilience, the focus should be on cork oak habitat conservation and multi-functionality, as also indicated by EU environmental policies, and on sustainable grazing in order to maintain ecosystem productivity. At the same time, in the general context of moderate expansion of the sector, strengthening the links between production and transformation in the national cork supply chain and dealing with the challenges posed by recent market trends might contribute to save the identity and peculiarities of the Italian cork industry.

Finally, the National Plan aims to coordinate national planning as well as regional and local activity to ensure the most effective use of resources available in the EU Rural Development 2014-2020. The National Plan also indicates the need for action throughout the supply chain: from the forests to industrial transformation enhancing, at every step, research and innovation.

Keywords: Italian Cork Plan, multifunctional forest systems, forest policy.

FROM GENETIC IMPROVEMENT TO GLOBAL CHANGE: WHAT ADVANTAGES AND THREATS FOR THE PRODUCTION, ADAPTATION AND EVOLUTION OF CORK OAK?

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Cork oak is a very important species for the Mediterranean region. Genetic improvement (G_I) is a vital component of modern forestry. In cork-oak the goal is cork quality to generate and multiply, for operational planting, high-yielding genotypes with enough diversity to buffer the future forests from environmental extremes. The establishment of a base population is typically followed by recurrent cycles of selection, recombination and progeny testing. Cork-oak G_I already benefits from provenance testing (International network FAIR 202), biological studies, including reproductive biology, genome sequencing, population of full-sibs and conservation of genetic resources. Yet it will likely be long and late on the delivery of gains due to the species high heterozygosity, long life, late and variable flowering and complexity of cork tissue. G_I for clonal forestry in cork-oak remains still limited due to the difficulty of mass production of cuttings and the reluctance of forest owners to pay higher prices. Estimative of the heritability (degree of genetic control) of cork quality and evaluation of cork quality in juvenile phase are essential to reduce time between selection and deliver of improved seed. Rapid advances in omics research offer increasingly valuable tools to enhance breeding but will not replace traditional methods in delivery of genetic gain. Work is in progress to locate genes responsible for cork formation and quality and marker-assisted selection. Inbreeding depression is a threat for the adaptation of cork-oak populations. The number of trees combining good cork quality and enough reproductive ability will likely be low as good acorn production occurs in less of 50% of the trees. An initial selection of 200-500 trees is prudent to assure a crossing population of 50-100 genotypes. Tree improvement of cork-oak is a long-term endeavour that will benefit from cooperation among countries for sharing genetic material, genetic testing and knowledge.

Global Change (GC) is a broad term to describe the effects of Human activity on Earth environments. It comprises climate change (CC), habitat destruction or fragmentation, species substitution, pollution, species extinction or expansion, erosion of genetic resources, disruptive processes in gene-flow and hybridisation, decline, changes in land use, increase in forest fires,

deforestation, intensive agriculture, incorrect silviculture, economically-invasive species, outbreaks of pest and diseases, and consumers' trends.

Cork oak is being affected by CC like most species and climates surely will change in the future, as they have in the past. The results (age 10-20) in the FAIR 202 trials show that some provenance are able to cope with strong decrease of annual rainfall indicating that CC, in rainfall, is probably not a threat for the future of the species. However, the critical changes in temperature may induce in phenology, interspecific hybridization and in acorn-dispersal fauna need further studies. CC may favour cork-oak whenever driving decline of other species. Incorrect silviculture covers a variety of factors that induce tree deterioration and decline, boosting pest and diseases and critically affecting the soil biome balance in mycorrhizae/root pathogenic fungi. Changes on consumer trends towards consent of non-cork stopper claims constant modernity on public awareness. Novelty on industrial products able to use sustainable amount of cork and sustainability in raw-cork prices are needed. Effects of invasive economically-species, agriculture and urban activities on population fragmentation and genetic resources are discussed. The environmental and economic costs of highly combustible species as *Pinus* and *Eucalyptus* in cork oak sustainability are discussed as well as the opportunities for resettlement created by rural abandonment. Correct forest management, assisted migration and conservation of genetic resources are important tools to mitigate the impacts of GC and CC.

Keywords: *Quercus suber*, climate change, FAIR 202 provenance trials, economically-invasive species, consumer trends.

A THREE-ACT PLAY: PENTACHLOROPHENOL THREATS TO THE CORK OAK FOREST SOILS MYCOBIOME

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Atmospheric release of persistent organic pollutants constitutes a silent threat through chronic contamination of soils at global scale; yet fundamental understanding of their occurrence, sources and fate is still largely lacking. This lecture, similar to our recent review in *Current Opinion in Microbiology* with equal title, will be presented as a three act play, comprising Setup, Confrontation and Resolution [1].

In the first - Setup, I will emphasize the eighty years of the history of pentachlorophenol (PCP) usage, only recently classified as persistent organic pollutant. PCP hazards will be reviewed in brief, prioritizing data that altered our perception about the biocide.

In the second - Confrontation, I will focus on active sources of PCP pollution, including inside cork oak forests. The so called cork taint defect in bottled-wines, which is largely associated with the presence of chloroanisoles, may be linked to PCP pollution as its microbial modification may generate pentachloroanisole [2]. However, PCP impacts in *Quercus suber* forests remain largely overlooked [3]. Though the bark behaves as a sampler accumulating both gaseous and particulate pollutants, PCP partition to the soil is likely to be substantial, raising the question of how the chronic exposure to this biocide is affecting the functional diversity of belowground microbes. In particular, of fungi that contribute greatly to preserve the functioning and ecological balance of forest soils.

Finally, as Resolution, the need for improved knowledge on the global distribution and impacts of PCP in soil microbial diversity as means to preserve the multi-functionality of terrestrial ecosystem will be emphasized. Accordingly, I will present our recent studies on the putative PCP degradation pathway used by the fungal community colonizing Tunisian cork oak forest soils chronically affected by the biocide [4]. Some of the identified PCP-derivatives may be also used as footprint of PCP environmental pollution, some of which can directly link the mitigation of the biocide with fungal activity. Overall, our studies are highlighting the superior capacity of the colonising fungal community to act as buffer against the disturbance caused by the biocide

in forest soils. Nonetheless, PCP prevalence in soil is also affecting biodiversity, probably inducing specialisation events in the colonising fungal community. To further address this, we have been performing additional community-based studies which are revealing key taxonomic and functional trends taking place in the fungal community during PCP mitigation (unpublished).

Keywords: Pentachlorophenol; chemical pollution; microbial diversity; forest soils; fungi; biotic degradation; degradation pathway

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CLIMATE CHANGE AND WOOD-BORING BEETLES: A NEW CHALLENGE FOR THE FOREST PROTECTION

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Change in climatic conditions may have at least three different types of consequences on the insect populations, such as reduction of development time with changes in the voltinism, variations in the geographic range with expansion northward and upward of insect species and shifting on new host trees, and arrival and establishment of new alien pests from warmer regions. These effects were investigated in model species of wood-boring beetles, which are among the most important forest pests.

Summer drought associated with high temperatures recorded in the last years has given rise to outbreaks of many bark beetles, including the spruce bark beetle (*Ips typographus* L.) in the southeastern Alps. From 1922 to 2016, precipitation during March-July recorded in the North-eastern Italian Alps has decreased of about 200 mm (-22%), whereas since 1962-2016 mean temperatures during the same months increased of about 2°C (+13%). Damage caused by *I. typographus* was inversely correlated with March-July precipitations of the previous year, while increases in spring temperature did not affect the insect development time but only its phenology. Earlier swarming of both overwintering beetles and first-generation offspring and the early start of the second generation allowed a more complete development of the second brood and a lower winter mortality. In conclusion, spring drought increases damage caused by *I. typographus* in the following year, whereas warmer spring affects insect phenology and survival.

The pine shoot beetle, *Tomicus destruens* (Wollaston), is one of the main pests of Mediterranean forests. Although *T. destruens* is oligophagous on Mediterranean pines, global warming may make the insect moving to higher latitudes and altitudes, encountering new pine species. A study was carried out to assess both the acceptance and performance of *T. destruens* offered to host and non-host pine species. A no-choice breeding experiment was set up under laboratory conditions, using logs of three host Mediterranean and two non-host continental pine species. *Tomicus destruens* colonised all tested pine species, but did not reproduce in the continental Scots pine. Differently, Austrian pine (which under natural conditions is usually not a host of *T. destruens*) allowed insect colonization and development with a breeding performance similar to that

observed in Mediterranean pines. In natural conditions, the first infestations of *T. destruens* on Austrian pines are already recorded in Spain, France and Greece.

Global warming associated to a quick international trade cause arrival and establishment of new alien pests mainly from warm regions. A recent study aimed at understanding the main mechanisms governing introduction and dispersal of alien bark and ambrosia beetles in Europe and USA. Value of imports was a strong predictor of the number of exotic species in both regions. At local scale broadleaf forests surrounding ports received larger number of alien species than conifer forests. By contrast, total forest cover in the landscape surrounding ports was positively related to the occurrence of native but not alien species. In the USA, warmer and wetter climate was positively linked to increased numbers of both native and exotic ambrosia beetles. Forest heterogeneity and climatic heterogeneity were key drivers in explaining patterns of species richness for native bark beetles but not for exotic species in both regions. Our findings suggest that the current climate change and the increasing international trade will likely lead to more establishments of exotic wood-boring beetles with concomitant negative effects on forest health in both Europe and the USA. Compared to Europe the risk of invasion appears however higher in the USA, especially for ambrosia beetles in the southeastern USA where the climate is highly suitable for exotic establishment.

Keywords: Bark and ambrosia beetles, forest pests, alien species, host-shifting, outbreaks

EUFORGEN TECHNICAL BULLETIN ON GENETIC CONSERVATION AND MANAGEMENT OF QUERCUS SUBER

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The European Forest Genetic Resources Programme (EUFORGEN)¹ is an international cooperation programme promoting conservation and sustainable use of forest genetic resources in Europe as an integral part of sustainable forest management. The Programme was established in 1994, following the adoption of the 1990 resolution by the 1st Forest Europe Ministerial Conference².

EUFORGEN has operated through networks and working groups that bring together scientists, policymakers and managers to exchange information, discuss needs and develop strategies and methods for better management of forest genetic resources. EUFORGEN has produced various outputs that help countries manage their forest genetic resources. These include guidelines and strategies for genetic conservation of forest tree species. This Technical Bulletin, of which the preparation was initiated in early 2000s by the EUFORGEN Network on *Quercus suber* and concluded only this year, is the result of such a cooperative effort.

This publication presents technical recommendations for the implementation of a long-term conservation and management strategy for cork oak (*Quercus suber* L.) genetic resources within the species' distribution area. It is intended to assist those who cherish the valuable cork oak genepool and its inheritance, either in the conservation of valuable seed sources or through its use in practical forestry and tree improvement. The focus of this Technical Bulletin is on conserving the genetic diversity of the species at the European scale.

Keywords: Genetic conservation, Genetic, *in situ*, genetic management, conservation

¹ www.euforgen.org

² Strasbourg Resolution S2 "Conservation of Forest Genetic Resources"
http://www.foresteurope.org/docs/MC/strasbourg_resolution_s2.pdf

ORAL PRESENTATION

Session 1: *Ecology, ecophysiology, health and genetic resources*



WHAT GENES MAKE PHELLEM A CORK?

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The outer bark of cork oak (*Quercus suber*) is uncommon because it accumulates pure rings of phellem tissue that provide the valuable thick cork used for industrial applications. Hence, cork oak is fairly well known as the source of raw material for the cork industry, but it is also a model system to better understand the molecular mechanisms at the basis of phellem growth and differentiation. Here, the 454 Platform (Roche) was used to analyze the cork oak outer bark transcriptome in comparison with that of holm oak (*Q. ilex*), whose bark consists in a typical rhytidome.

The identified genes were classified in the following categories: carbohydrates, amino acids, acyl-lipids and isoprenoids metabolism; cell wall; transcription factors; phytohormones; meristem-related genes; and integrators of environmental cues. Both bark transcriptomes reflected similitudes in their complexity or number of genes represented but some categories such as secondary metabolism, carbohydrates and lipids metabolism were found to be more induced in cork oak. DEGseq package showed that 16% of genes were differentially expressed between cork and holm oak outer bark libraries. This differential expression was confirmed by Real time PCR for a group of selected genes.

Our results suggest a relevant role in phellem tissue for hormones such as auxin, ethylene and ABA. They also provide new insights into the regulation of phellem at transcriptional and epigenetic levels. Globally, this study provides a comprehensive view of the phellem transcriptome and identifies some candidate genes that may explain some specificities of the unusual cork oak bark.

Keywords: cork, cork oak, holm oak, suberin, RNA-seq

CORK SEASONAL GROWTH: A TRANSCRIPTOMIC OVERVIEW

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Cork (phellem) is a water-resistant tissue that constitutes the outer bark of trees. It is made of suberized cell walls that protect the plant from dehydration and pathogens attack. The cork oak (*Quercus suber*) produces a particularly thick and pure phellem, widely used for industrial applications. However, the commercial value of cork depends on the environmental factors occurring during its formation.

To understand how cork formation is modulated we analysed the cork oak transcriptome by sequencing the cork tissue during the growing season. A minimum of three replicates were harvested and sequenced using Illumina platform and further validated by qPCR analysis at three different time points, April, June and July, selected by their contrasted temperature and humidity conditions. Specifically, April corresponds to the growth initiation after winter pause, June to the maximum growth of the tissue, and July to a high tissue growth but under stressful summer conditions.

The transcripts identified by RNAseq were functionally annotated using Blast2Go platform and manually classified using literature. The comparison between time points showed that the transcriptome was highly similar during the cork maximum activity (June and July), but highly differs when the cork growth starts (April). Differentially expressed genes between months were grouped according to their expression pattern in 5 clusters, showing that when temperature is relatively low and humidity high (April) the genes related with meristem regulation and cell wall modification were upregulated, whereas when temperature is higher (June and July) the upregulated genes were related with stress, synthesis of fatty acids and secondary metabolism. Our results shed some light to the cork development and may allow the identification of new candidate genes to be used as markers of quality-cork to assist plant breeding.

Keywords: cork, suberin, RNA-seq, transcriptome, cork growing season

SIMULATION ANALYSIS SUGGEST *QUERCUS SUBER* x *QUERCUS ILEX* HYBRIDIZATION COULD BE UNDERESTIMATED

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Previous studies on cork and holm oak hybridization have focused on the detection of hybrid individuals in natural populations, using a set of 8 nuclear microsatellites and the Bayesian approach implemented in the software STRUCTURE and NEWHYBRIDS. The current rate of hybridization between these species has been estimated in approximately 1%.

In this work, we have used virtual hybrid individuals to check the reliability of this estimation. We have developed a software program for the simulation of mixed populations under different demographic scenarios (population size for each species, fitness and fertility among specific classes, etc.). Allele frequencies obtained for natural populations in previous studies were used to assign the genotypes of the virtual individuals in the initial populations. Several reproductive events (“generations”) were simulated, allowing the production of virtual pure species individuals, F1 hybrids and backcrosses, with known pedigrees. Identification of virtual hybrid individuals with STRUCTURE was then assessed. Our results show that, although F1 hybrids are usually accurately identified, an appreciable number of introgressed individuals are missed with this methodology and this set of molecular markers. Thus, the actual rate of introgression between cork and holm oak is very probably higher than reported previously. Additionally, we have found that, although the q_s parameter (representing the probability of the individual of being a pure cork oak) provided by STRUCTURE with this set of markers is not reliable to properly assign the specific class of introgressed individuals, comparison of this parameter between a hybrid tree and its progeny (produced by pollination by purebred trees) can be used to identify the species of the pollen donor and the direction of introgression. Anyway, a more powerful set of markers is needed for the accurate identification of introgressed individuals and estimations of hybridization rates.

Keywords: Hybridization, Introgression, Simulations, Molecular markers

MOLECULAR EVIDENCE OF BIDIRECTIONAL INTROGRESSION BETWEEN *QUERCUS SUBER* AND *QUERCUS ILEX*

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Cork oak and holm oak share a great deal of their natural range, and are known to hybridize in mixed stands. This hybridization is supposed to have played a relevant role in the past history of cork oak. Preferential backcrossing of F1 hybrids with cork oak (also supported by phenology) could have helped cork oak survival in adverse climatic and soil conditions and would have caused the organellar introgression observed nowadays in Eastern Spain and Southern France, while no traces of introgression have been described in holm oak.

In this work, we have checked if hybrids actually backcross preferentially with cork oak, due to phenology or to any genetic incompatibility, or if they can backcross also with holm oak. For this purpose, we have analysed the progeny of 4 hybrids from a natural mixed population with 8 nuclear microsatellite during 3 campaigns and have used the STRUCTURE software to assign the probability of each seedling of being a pure cork oak (q_s) or a holm oak (q_i).

According to simulations studies, the q_s parameter with these markers very often would classify advanced introgressed individuals as purebreds. Notwithstanding, we have found that the comparison of this parameter obtained for a mother hybrid tree and its progeny (produced by pollination by purebred trees) allow the identification of the species of the pollen donor and, thus, the determination of the introgression direction.

Application of this method to our hybrids revealed their pollination both by cork oak and holm oak. Each hybrid was predominantly pollinated by the most abundant species in its vicinity, which suggests pollination is determined by the abundance of available pollen at the moment of female flowers receptivity. However, other factors such as genetic incompatibilities or “preferences” cannot be completely discarded. These results are consistent with previous identification of adult hybrids in the field, which pointed to bidirectional introgression.

Keywords: Hybridization, Introgression, Pollen availability, Molecular markers.

LEAF MORPHOLOGY OF PROGENIES OF *Q. SUBER*, *Q. ILEX*, AND THEIR HYBRIDS USING MULTIVARIATE AND GEOMETRIC MORPHOMETRIC ANALYSIS

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The genus *Quercus* is known for the occurrence of frequent hybridization events between species. Although this phenomenon is not common among holm oak (*Q. ilex*) and cork oak (*Q. suber*), these species hybridize when they coexist in mixed stands. The result of hybridization is a viable hybrid progeny with a very heterogeneous leaf morphology.

Literature concerning the leaf morphology of suber-ilex hybrid seedlings is scarce, and non-existent from a quantitative point of view. In the case of the leaf morphology of hybrids and their progeny, it has been observed a high frequency of leaves with fluctuating asymmetry or developmental abnormalities, which can have a marked effect on fitness.

In this work, we have characterized seedlings' leaf morphology corresponding to one and three year-old half-sib progenies of holm oak, cork oak and their hybrids. For this purpose three to ten leaves of each individual were collected, and two methodologies were used for analysis. Firstly, we used a classic morphological analysis of twelve variables that were reduced using multivariate techniques. On the other hand, shape of the leaves and presence of fluctuating asymmetry were thoroughly analyzed by geometric morphometric analysis methods.

The results indicate that size and thickness are the most discriminating traits between species, and that the hybrid progenies do not show a third different phenotype regarding the parental species, but they have similar leaf characteristics to one of the parents, generally showing greater similarity with cork oak.

Geometric morphometric analysis is a more appropriate methodology to study shape than the classical multivariate techniques. Using this method, it has been quantified the extent of fluctuating asymmetry (FA) and the presence of developmental abnormalities of seedlings. The results suggest that asymmetries in leaves are probably due to genetic stress, although we cannot completely discard an influence of environment, to some extent.

Keywords: Hybridization, fluctuating asymmetry, leaf morphology, Procrustes analysis, *Quercus*.

GENETIC STRUCTURE OF *QUERCUS SUBER* POPULATIONS IN SARDINIA FOR THEIR EXPLOITATION AS SEED STANDS

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Sardinian cork oak (*Quercus suber* L.) stands cover more than 20% of the regional territory where they have a relevant socio-economic and ecologic importance. The quality of cork is controlled by the interaction of genetic and environmental factors. In this paper, we report on population genetics of eleven populations from the main cork production areas of Sardinia analyzed by nuSSRs aiming to investigate the pattern of genetic variation searching for inbreeding and among-populations variation. The populations of *Q. suber* were investigated for discriminating among population genetic characteristics and cork quality (reported in another paper by Ducci et al.) in relation to some environmental parameters. This work is preliminary to the definition of seed zones and registration of some populations as seed stands, for future planting activities with certified materials.

Six primers selected in the literature for the *Quercus* genus were selected and used in combination for amplification of DNA fragments. The products were sequenced and the allele frequencies matrix was analyzed in order to determine population genetic characteristics (He and Ho, Fis, Fst, Fit, etc). Further, clustering allowed to check relationships among populations and if different gene pools were detectable in the region.

Keywords: cork oak, SSR, seed zones, Sardinia, *Quercus suber* genetic resources

THE CERTIFICATION OF CORK OAK REPRODUCTIVE MATERIAL IN SARDINIA FOLLOWING THE 1999/105/CE DIRECTIVE

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To increase the stability, adaptation, resistance, productivity and diversity of forest ecosystems the 1999/105 EU Council directive stressed the importance of using high quality forest reproductive material (FRM) which is genetically and phenotypically suited to each site. It is implemented in Italy by the Legislative Decree 386/2003 which sets the rules for the approval of *basic material* for the production of FRM to be certified as 'source-identified', 'selected', 'qualified' or 'tested'. The decree appoints the Italian Regions as *Official Bodies* for the control, marketing and quality of FRM. In 2010 the whole Region of Sardinia was recognized as a *Region of Provenance* and in 2012 the Regional Government (decision n. 38/11 of 18/09/2012) defined the role of different players in the FRM regional production and control system.

The Sardinian Forest Agency (FoReSTAS) is in charge of implementing the procedures for identifying the *Seed Sources* and *Stands* within the regional forests and for producing FRM in the 'source-identified' and 'selected' categories. FoReSTAS manages 18 plant nurseries, six of which are devoted to conservation purposes. Following the activities carried out, in 2017 the Agency will be able to produce 'source identified' plant materials of *Quercus suber* L., *Quercus ilex* L. and *Quercus pubescens* Willd. (all included in Annex I of the EU Directive). This is crucial for the protection of Sardinia's forest ecosystems as calls for Rural Development Program (PSR) measures on reforestation are being opened. The lack of certified FRM has contributed to the failure of previous PSR (2007-2013) measures.

Phenotypic and genotypic characterization of cork oak basic materials is being carried out by FoReSTAS and the Forestry Research Centre CREA SEL, within a three-year research project coordinated by the University of Sassari, with the aim of contributing to FRM production in the 'selected' or 'qualified' categories.

Keywords: forest reproductive material, cork oak, region of provenance, Sardinia

BIENNIAL FRUITING IN CORK OAK

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Cork oak belongs to section *Cerris*, which is characterized by species that are able to produce acorns of annual (6-8 months) and biennial maturation (18-20 months).

The study has been made all over Portugal territory in several plots and by observation in scattered trees.

The results show that some trees only produce acorns of annual maturation while others are capable of producing both types, annual and biennial. No trees producing only biennial acorns have been identified. In some trees, it was observed the fall of all immature biennial fruits, becoming in practice annual-acorn type trees. The biennial fruiting capacity tends to be systematic at the individual level which leads to consider the hypothesis of genetic and/or epigenetic control in the formation of this type of fruit.

Observations were made in regions with a very diverse climate, but so far no climatic pattern has been found associated with biennial-fruited.

The production of both types of fruits increases the genetic variability of offspring, since they were formed under different pollinating events.

Accurate separation of the two types of acorns is critical for parental studies either in quantitative or molecular genetic studies. The separation must be performed while annual acorns are still immature which happens, in Portugal, during few weeks in August/ September.

The simultaneity of the two types of fruits also increases the probability of hybridization events and introgression.

The processes and factors that lead a part of cork trees to produce the two types of acorns are certainly complex but still not fully explained. The reproductive biology of biennial acorn production requires more years of phenotypic observations complemented by studies of biology and molecular genetics, proteomics and metabolomics, photosynthetic efficiency and water use, and very detailed climatic data in order to identify the factors that control and trigger this behaviour.

Keywords: *Quercus suber*; annual fruiting; flowering phenology; genetic variability; hybridization

IDENTIFICATION OF CORK CHARACTERS FOR PHENOTYPIC SELECTION

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Global change effects can determine major changes in species distribution and productivity. In the Mediterranean region of the severity of hot and dry periods is growing and an increased frequency of extreme events and a major vulnerability of natural ecosystems is evident. Cork oak (*Quercus suber* L.) is widely spread in the West Mediterranean region and its economic and social is important. Managing properly genetic resources is fundamental to preserve diversity and to increase the resilience of species, that assumes major importance in so sensible and delicate social, economic and ecological systems. This study is aimed to consider the phenotypic selection of basic materials for cork traits. Therefore, not only tree shape or wood production phenotypic traits as usual in most forest tree breeding programmes (EU Directive 1999/105/CE). The innovative idea is to introduce traits related to cork quality in the European FRM legislation. Cork samples (100 cm²) were collected from almost 30 mature trees in candidate seed stands in the stripping season. Trees were randomly sampled in three subareas/stand along an altitudinal gradient and characterized phenotypically for growth and shape traits. Traits were measured on Cork specimen keeping as a reference the main commercial requirements. Fresh and dry weigh were measured to estimate the percentage of empty volume determinate by slits, patchy, and insect damages. Damaged areas by slits, patchy, and insects were measured in transverse and tangential sections. Image analysis techniques were applied to measure lenticels (ImageJ program - image processing and analysis in JAVA) as well as outer and inner cork surface were measured for roughness and porosity. Data were managed to perform the multivariate Factor Analysis to identify the most significant cork traits to for seed stand selection and knowing the cork quality variation in Sardinian stands. Keywords: phenotypic selection, breeding, cork quality, Sardinian cork oak, *Quercus suber*

PROVENANCE BEHAVIOUR IN THE CORK-OAK INTERNATIONAL NETWORK TRIALS FAIR 202

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The international network of provenance trials in cork-oak was established as a result of the EU Concerted Action FAIR 202, 1995-2000. 34 provenances were selected in the natural range of cork oak and trials were established in 1996/97 in France, Italy, Portugal, Tunisia and Spain. This study compares the behavior of provenances in the trials of Grighini (Sardinia), Monte Fava and Quinta da Nogueira (Portugal), Monfrague (Spain), Les Maures (France) and Tebabe (Tunisia). Observations on total height (Ht) and diameter at breast height (DBH) are used to compare and assess adaptation within sites and among sites. Climate at the provenance site seed collection and at trials sites is used to characterize the behavior of provenances. The results reveal that the provenances, ES 5 (1063 mm), IT16 (910 mm), IT12 (937 mm), 937, TU32 (948 mm), FR2 (958 mm), FR1 (963 mm, MA31 (970 mm), ES8 (993 mm) are able to adapt and show good growth under conditions of decrease of total annual rainfall and strong decrease in case of TU33 (1610mm), MA27 (1280 mm). On the other hand provenances coming from sites of low precipitation not always show relevant performance in sites of higher precipitation as IT14 (448 mm), ES10 (455 mm), MA29 (479 mm). These results are discussed in the impact climate change (CC) may have in adaptation and evolution of cork oak. Our results show that cork oak will not face serious threats if drought increases in the Mediterranean region, since some populations are showing capable to cope successfully with decrease of total precipitation. The ongoing results from the cork-oak international network trials FAIR 202 show the importance of this line of research and the need to establish harmonized criteria on data collection to enhance the comparability. As cork quality is a key issue on cork-oak economic sustainability it is critical to establish harmonized criteria in cork harvesting for further studies to compare cork quality with special reference for the assessment of the genetic control of cork production and heritability.

Keywords: *Quercus suber*, Climate Change, adaptation, selection, plasticity and epigenetics

ONE YEAR MONITORING OF BUD BREAK PHENOLOGY IN A FAIR 202 (GRIGHINE, SARDINIA) INTERNATIONAL FIELD TEST

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Phenology, the study of recurrent biological events and biotic and abiotic factors that determine them, allows to know how a species respond to seasonal environmental events. In phenological traits analysis, the variance components due to the climate effects as well as the genetic one are important. These traits are characterized by high heritability and genetic variability and are considered important adaptive traits, able to influence species distribution and fitness in response to variations of air temperature and water availability. The monitoring of phenology is considered a useful tool to investigate the species adaptability in a climate change scenario.

In the framework of the Sardinian regional project “Cork Oak woodland multifunctionality” bud break phenology of 15 *Quercus suber* L. provenances, randomly distributed on 15 blocks, were monitored in Grighine IUFRO - FAIR CT 1 95 0202 (1996-2000) experimental field test (Oristano, Sardinia, Italy; 8°48'53 "E; 39°55'35" N; 410-440 m asl). There, 17 genetic entries (provenances and progenies) were tested. This material is representative of the cork oak Mediterranean range.

Between 25.03.2016 and 28.05.2016, once a week, flushing data were collected according to a scoring method. As monitoring was carried out on adult trees, bud break was observed on terminal bud of lateral branch, using and comparing the international BBCH method and the standard protocol defined for oaks at European level by TREEBREDEX and Trees4Future Projects.

For monitored provenance data were analyzed to know both the main flushing critical dates (onset and cessation) and dynamics of shoot elongation. Logistic interpolation was used to estimate bud break daily dates starting from weekly observations.

Keywords: *Quercus suber*, cork oak, provenances, phenology, adaption

PHYSIOLOGICAL VARIABILITY OF CORK OAK TREES IN RESPONSE TO INCREASINGLY DRY YEARS

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Climate change scenarios forecast higher mean annual temperature (up to 5°C), precipitation reductions (up to 40%), lower superficial soil water content and runoff (~100mm.yr⁻¹), longer summer droughts, and more frequent extreme events in the Mediterranean region, including severe droughts (IPCC, 2014). Climate changes may induce a diversity of responses known as phenotypic plasticity, which constitutes the main mechanism by which plants can cope with new environmental conditions.

Here we aim to analyze the variability in the physiological responses to increasing drought of 18 cork oak trees planted in a Mediterranean savannah-type woodland of southern Portugal in 1988. Physiology of the selected trees was studied under ambient conditions, on a typical year, a moderately dry year and an extreme dry year with a severe winter to spring drought. The seasonal and inter-annual evolution of tree variability of phenology, water status, transpiration, leaf gas exchange, xylem $\delta^{18}\text{O}$, and social competition are presented as influenced by contrasting micrometeorological conditions and the multiscalar drought index SPEI.

The variability of cork oak leaf predawn water potential (LWPpd), gas exchange, sap flow and xylem $\delta^{18}\text{O}$ was minimum in winter and maximum during the summer period, respectively peaking in July, early- and late September. The maximum photosynthetic rate (A_{max}) was best correlated to xylem isotopic signature ($r = -0.94$) as well as SPEI6 ($r = +0.83$). Likewise leaf bulk $\delta^{13}\text{C}$ was negatively correlated to SPEI6 ($r = -0.85$), A_{max} ($r = -0.80$) and LWPpd ($r = -0.74$).

Our results show that in our experimental area, cork oak physiological performances and variability are strongly associated to rooting depth and groundwater access. The expected consequences of future climatic conditions according to scenarios RCP 4.5 and 8.5 in the region and the resulting increase of dryness and collapse of groundwater recharge are discussed.

Keywords: Tree variability, increasing drought, SPEI, groundwater access

PHOTOACOUSTIC SPECTROSCOPY FOR ESTIMATING NUTRITIONAL INDICES IN LEPIDOPTERAN DEFOLIATORS

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Lymantria dispar L. and *Malacosoma neustria* (L.) are the most serious defoliators of cork oak in the Mediterranean region. For this reason, information on their feeding behaviour are important in pest management. A non-destructive approach by using photoacoustic spectroscopy (PAS) combined with a partial least squares regression analyses (PLS), has been used to provide a rapid and cost-effective analysis to assess foliage chemistry and to estimate some nutritional indices of these insects. For testing the performance of larvae, cork oak leaves for chemical, spectroscopic analysis and bioassays were collected during the cork oak vegetational season. Leaves were analysed for their water content, polyphenols, tannins, condensed tannins, amid, nitrogen and carbon according to standard chemical protocols. Waldbauer's method was applied to determine the following indices: Relative Growth Rate (RGR), Relative Consumption Rate (RCR), Efficiency of Conversion of Ingested food (ECI), Approximate Digestibility (AD), Efficiency of Conversion of Digested food (ECD).

Chemometrics of PAS/PLS regression analysis produced adequate prediction algorithms for the studied chemico-physical and nutritional parameters. Multivariate analysis of data showed good relationships between the consumption and utilization of food by insects and nitrogen, condensed tannins, polyphenols, water content in foliage. Moreover, the relative based PAS/PLS models enabled the prediction of some chemico-physical constituents of foliage as nitrogen ($R^2=0.85$), condensed tannins ($R^2=0.72$), polyphenols ($R^2=0.84$), water ($R^2=0.82$) and ECD and ECI indices both for *Lymantria* ($R^2=0.82$; $R^2=0.61$, respectively) and *Malacosoma* ($R^2=0.71$; $R^2=0.66$, respectively). The proposed approach showed to be very useful for investigating the insects feeding behaviour and for obtaining leaf chemico-physical data and nutritional indices acquiring only the PAS spectra that can be collected quickly and at low cost.

Keywords: cork oak defoliators, nutritional indices, foliage chemistry, photoacoustic spectroscopy, Chemometrics

EPIDEMIOLOGICAL CHARACTERIZATION OF *PLATYPUS CYLINDRUS* (Col., CURCULIONIDAE, PLATYPODINAE)
ATTACKS IN A CORK OAK STAND OF M'SILA IN THE NORTH-
WEST OF ALGERIA.

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Platypus cylindrus is an important biotic agent directly involved, in recent years, in cork oak decline especially after decorking. The study of epidemiological characteristics of this pest and the relationship with its plant-host has been conducted in a coastal forest of the north west of Algeria.

Two young plantations decorked in summer 2007 were selected to follow up its attacks: rate and intensity of infestation. Colonization of 333 tree-samples was assessed by counting the monthly insect penetration holes recognized by the presence of sawdust along the trunk. These trees were also subject of various statements: tree characteristics (weakness, dimensions) but also exploitation methods (decorking intensity).

After more than three years of observation and follow-up (December 2007 – August 2012), the results show two different periods: (i) December 2007-February 2009: an increase in the rate of trees infestation following an average density of 22-130 holes/m²; (ii) March 2009- August 2012: a gradual regression in the rate of attacks over time to cancel from January 2012.

Mass population of the insect on trees is not random but follows a clear strategy linked to the trees characteristics: dimensions (height < 6 m, the circumference at 70 cm; exploitation (decorking coefficient > 2.5, 1.5 m height); health (weak and dying trees) and climate (air warming M = 29,6°C).

Keywords: *Platypus cylindrus*, *Quercus suber*, decline, infestation, decorking, Algeria

IMPACT OF PINE INVASION ON THE TAXONOMIC AND PHYLOGENETIC DIVERSITY OF TYRRHENIAN CORK OAK FORESTS

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Invasion by non-native tree species is a major driver of reduction and fragmentation of forest ecosystems, also altering biodiversity components. However, the effects of this process on the phylogenetic structure and diversity of Mediterranean woodlands are still unknown. Accordingly, we used cork oak (*Quercus suber*) stands invaded by self-sowing populations of maritime pine locally introduced ca. 70 years ago as a model system to assess the impact on the taxonomic and phylogenetic diversity of the native seed plant community. We performed vegetation sampling of the two forest types in sites of Tuscany with similar conditions. Taxonomic diversity was negatively affected by the pine at three levels (gamma, alpha and beta). Indicator species were significantly less numerous than in cork oak stands, and did not include two growth-forms such as herbs and vines. Phylogenetic diversity metrics were inferred from an evolutionary tree of seed plants based on a ITS-5.8S nuclear DNA dataset including original sequences from local plant material. Phylogenetic diversity (PD) was positively related to species and genus richness, showing a marked decrease in the pine stands. Seven major clades (orders) of angiosperm dicots were only represented in the cork oak community. Both the NRI and NTI indices showed a significant reduction of phylogenetic evenness in the pine forest. Here, the proportional increase of related taxa with acid-tolerance specialization suggests that soil acidification is a major driver for a “habitat filtering” effect causing the exclusion of several understorey species and genera of cork oak forests. Progressive thinning of the pine stands is advocated to avoid further acidification and promote the re-conversion to oak woodlands by natural regeneration. This will ultimately favor the recovery of the associated plant diversity and the restoration of a vanishing forest ecosystem of the ancient Mediterranean landscape.

Keywords: Invasive species, Cork oak forests, Pine tree, Phylogenetic diversity, Species richness

ORAL PRESENTATION

Session 2: *Forest monitoring and management, land and forest planning*



LAND PLANNING FOR FOREST MANAGEMENT, THE ARCI GRIGHINE (SARDINIA) STUDY CASE

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Since forest management interacts deeply with the land system, in a sustainability perspective, it requires a proper planning framework. Different needs play a role, like 'internal planning', seeking optimal company results, or the 'required planning', necessary to take account of society-driven requests and limitations on forestry activities. Public financial support is generally necessary and can be very well justified, considering the social interests involved. The work emphasizes that, in implementation of the regional plan approved in 2007 (PFAR), public investments on land planning at the district level (PFTD) deserve the highest priority.

PFAR has envisaged a PFTD for each of the 25 districts that make up the region. The plan for the Arci Grighine District (PFTD-AG) is the first that the Region has undertaken. A proposal for a fully developed plan has recently been delivered, the materials of this work are derived from the that plan. The paper presents the experimental systemic approach to the construction of coherent, complex and significative district level forest management strategies, created in the course of the PFTD-AG development.

The complexity of the territorial system is functionally represented by the diversity of categories of patches, each patch being distinct from adjacent by a different combination of activity levels. Meaningful disjoint territorial sub-systems have been identified organising, in an appropriate hierarchical structure, the factors discriminating among activity options. Such sub-systems are discontinuous territorial entities inherently heterogeneous, that share one or few characteristics related to forest management. The district planning level, allowing a broad and deep analysis of the environmental and socio-cultural structure of the land system provides, through the sub-systems, a dynamic approach to decision making, (i) promoting the use of production potential, (ii) allowing the responsible consideration of the necessary limitation of certain activities and (iii) ensuring that proper care is taken of the existing threats.

Keywords: systemic forestry, cork oak forest management, cultural value of silviculture

TREE DIAMETER GROWTH MODEL FOR CORK OAK STANDS IN PORTUGAL

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Tree diameter growth is influenced by several factors such as the environment (soil and climate), stand characteristics, tree size, and intra-tree competition. The interaction between individuals in the Mediterranean region has more impact on the competition for water and soil nutrients rather than the one for light. In the case of cork oak forests, tree diameter growth models may improve forest management by (i) predicting the tree status in the future and (ii) helping to determine the age at which a cork oak tree may be debarked for the first time. The goal of this work was to develop a model for the estimation of the tree diameter growth considering at the same time its surround environment, its stand characteristics and the tree intra-specific competition. The dataset used for this study, includes different stand stages of the development, stand characteristics, debarking rotation intervals (from 9 to 14 years) on permanent plots spread along the distribution area of the cork oak in Portugal. This wide dataset enhanced the awareness to develop a more accurate tree diameter growth model that can predict throughout different stand stages and its characteristics. A diameter growth model developed as a function of tree and stand characteristics was compared to a model developed from a potential growth function multiplied by a modifier function expressing competition. It was expected some improvement in the precision of the latter, although differences may not be relevant.

Keywords: cork, diameter increment, modifier function, competition indices

MICRO-GRANULATE CORK STOPPERS: STUDY ON OVERALL AND SPECIFIC MIGRATION

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A new type of agglomerated cork stopper, generically called "micro-granulated cork stopper" or "micro-agglomerated cork stopper", is increasingly widespread on the wine market. It is identified by each cork factory with different names and is defined by the ISO 633:2007 as "agglomerated cork stopper-treated cork". It is a "stopper obtained by agglutination of cork granulates grain size between 0.25 and 8 mm, with addition of an adhesive and having at least 51% of cork granulate by mass".

Despite the alarming news that sometimes occur on food contamination by substances released to wine from these type of closure, no scientific reports have been done till now to detect the extent of the problem. This work aims to evaluate both the sum of all substances (Overall Migration - OM) and the individual molecules (Specific Migration - SM) that are able to be transferred from micro-granulated cork stoppers under specific time-temperature conditions and different simulant solutions as stated by the EC Regulation 10/2011, DM 21/03/1973, and ISO 10106:2003.

Replicate migration trials involved samples of micro-granulated cork stoppers and natural cork stoppers (as controls) that were both fully immersed (worst conditions) in simulant solutions and put in contact only with one stopper face (real conditions). Molecule identification was carried out by means of target and non-target MS analysis coupled with UHPLC system and MS-Q-TOF detector (UHPLC/Q-TOF).

Results highlighted variable values for OM and SM according to the test conditions including contact time, temperature and test medium (type of simulant solution). OM and SM limits (OML and SML) were exceeded by few samples of micro-granulated cork stopper under worse conditions than those of foreseeable use for closing and storing bottled wines.

Keywords: closures, food contact, migration, packaging, wine.

COMPETITION PATTERN IN YOUNG CORK OAK STANDS

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The area of cork oak plantations has been increasing in Portugal, not only in forest, but also in agricultural land, with soil characteristics distinct from the current mature stands in a productive stage. It is well known that competition influences tree growth pattern and the stand structure. In young stands, the individual tree relative growth rate is decreasing exponentially on tree size before the onset of competition; and switches to an increasing pattern when small trees become dominated by large trees. The aim of this study was to understand at which stage of the stand development in young cork oak stands does competition unfold and which type of competition was in place. For this analysis, remeasurement data from permanent plots on juvenile stands located across the cork oak Portuguese area were used. This analysis was performed in different steps. The stand structure was analyzed by computing the coefficients of asymmetry and kurtosis of the diameter and height distributions as well as the Gini coefficient (which gives information on stand variability). The tree relative growth rate over the tree size was analyzed for the diameter at breast height. The impact of stand density measures on the height-diameter curve was studied. As a result of this study, it is possible that the current spacing used on cork oak plantations may not lead to tree competition before the second cork extraction. Thus, the systematic removal of trees, without any knowledge on tree cork quality, should be avoided. Instead, it is suggested that the thinning procedure for decreasing tree density should be carried out at the second cork extraction, since, only at this moment, cork growth and cork quality can be assessed.

Keywords: relative growth rate, asymmetric competition, symmetric competition, cork quality

LAND USE CHANGE IN A SILVOPASTORAL CORK OAK SAVANNA IN CENTRAL SARDINIA

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Cork oak woodlands in Central Sardinia represent a biocultural landscape related to silvo-pastoral and agro silvo-pastoral systems where the forest component is dominated by *Q. suber* on soils developed mainly from siliceous (granite) rocks.

These systems provide various ecosystem services: carbon sequestration, water quality, biodiversity and soil conservation in addition to animal, wood and non-wooden productions (e.g. milk, beef, wool, pasture, cork, acorns...). Otherwise, these multifunctional systems are affected by scarce natural regeneration and low health conditions of trees, as well as documented also for Portuguese *montados* and Spanish *dehesas*. In Sardinian cork oak savannas density is higher and Sardinian dairy sheep represent grazing component.

Previous studies in the area compared land use in four plots, in Nuoro district in the years 1954, 1977 and 1998. Focusing on cork oak landscapes, the work verified a change of 30% of “pure” cork oak stands to woody pastures and Mediterranean maquis. The main causes have been the decreasing trend of cork prices in international markets and the CAP payments for livestock more convenient for owners than those for forest management. Wildfires have also contributed to the degradation of the forests.

This work aims to update land use changes, integrating the previous study results with new sources of information: land use database (year 2008), 1:25000 by Autonomous Region of Sardinia. The research produced, through Geographic Information Systems tools, new information and change maps from 1998 to 2008. Results show a loss of 787 hectares of “pure Cork oak” in 10 years for the 10,054 ha plot area (7.8% of the total surface), mainly by change to “other types of forest” and “wooded pastures”.

Local silvo-pastoral system in plot areas seems today to be not capable to adopt technical solutions to harmonize different farming goals such as reduction of grazing animals, pasture rotation and/or ameliorating. Effective measures and a regional plan in favour of restoration of cork oak woodlands are expected

Keywords: Land use, Land cover, Forest transition, Spatial dynamics

MONITORING CORK OAK OPEN WOODLANDS WITH PROXIMAL REMOTE SENSING

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Oak woodlands are very important for Portugal and other Mediterranean countries, both economic and ecologically. The maintenance of the ecosystem services provided by this type of forests depends on human use and management. This study is conducted in a cork oak woodland, composed of different Plant Functional Types (trees, shrubs, herbaceous vegetation). Spectral data are collected *in situ* in order to monitor the phenology and productivity of the three PFT, using a field spectroradiometer and pole-mounted NDVI and PRI sensors (continuous measurements). The main goals are to select the most appropriate vegetation indices (VIs) for this type of open, spatially heterogeneous forests, and to assess the relationship between climatic factors and VIs, used as proxies of biophysical characteristics (e.g. leaf area index, light use efficiency).

Results show marked differences in the NDVI temporal trends among the oak canopy, the herbaceous layer and the shrub species. In the cork oak, changes across time are small (0.7 to 0.85) and related with leaf ontogeny. The herbaceous layer has the largest NDVI range (0.2 to 0.7), with low values during the senescence. In the case of shrubs, the decrease of NDVI during summer is dependent on the species, being larger for *Cistus* (semideciduous) than for *Ulex* (evergreen). The correlation between climate and VIs revealed contrasting patterns between VIs related with green biomass (e.g. NDVI or NDWI) and those representing photosynthetic efficiency (e.g. PRI). The relationship between VIs and temperature, radiation, and vapor pressure deficit for cork oak was opposite to that observed for the herbaceous layer and *Cistus*. No significant correlations were observed between rainfall and vegetation indices in cork oak and *Ulex*. This study, while confirming the ability of VIs to monitor the temporal dynamics of biophysical properties, evidence the importance to consider ecosystem composition (PFTs) for a correct interpretation of results.

Keywords: Mediterranean forests; *in situ* spectral measurements; vegetation indices; spatial heterogeneity; plant phenology

USING TERRESTRIAL LIDAR FOR MONITORING CANOPY STRUCTURE IN CORK OAK TREES

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Information on forest canopy structure, is required at a wide range of spatial scales for several environmental applications (ecosystem productivity model, ecological and forest management, disease and stress detection). Aerial laser scanner (ALS) demonstrated to be a promising techniques and an important source of precise and accurate information in forestry quantitative studies at landscape level. More recently several studies that have been published reported different potential applications of the terrestrial laser scanner (TLS) for forest stand and canopy variables estimation at plot level.

TLS allows the acquisition of very high volumes of data and high resolution point clouds that can potentially and productively be used to derive single tree attributes by post-processing of TLS point clouds.

The main aim of this work was to assess the capabilities of terrestrial laser scanner in measuring both changes by the time and differences among trees of canopy characteristics of *Quercus suber* L. (cork oak) plants.

The field measurements have been conducted in an experimental farm owned by the University of Sassari located in Oristano (Italy) on seven cork oak trees. For four years (from 2013 to 2016) TLS scans were periodically taken for each tree. After a voxelization process a segmentation method for discriminating foliage from wood was developed. Then, changes in canopy volume density and in radial growth of trunk were estimated by TLS scan results.

Analysis of results showed that the segmentation algorithm that was developed, accurately discriminated wood and foliage clusters. In addition, TLS technique was enabling to measure temporal changes on radial growth of cork oak trees. Finally, it was able to identify differences in crown density among plants. In conclusion, the results of this study suggested that TLS technique could be a promising tool for describing and monitoring the canopy structure also for broadleaf trees.

Keywords: Terrestrial laser scanner (TLS), forest inventory, wood volume, crown volume, *Quercus suber*

RECENT DYNAMICS OF FOREST FIRES IN *QUERCUS SUBER* STANDS IN SARDINIA, CORSICA AND CATALONIA

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Quercus suber L. forests cover large areas of the Mediterranean landscapes, and represent a key source of income and jobs related to the harvesting and transformation of the cork bark. Furthermore, cork oak forests are associated with high biodiversity and conservation value, and also provide a number of goods and services (e.g.: pastures, leisure activities, beekeeping, mushrooms, shelter for animals). The most relevant disturbance for *Quercus suber* stands, as well as for Mediterranean forests, is represented by forest fires, although cork oaks are able to survive and resprout (from stem buds or basal buds) after fire. In the Mediterranean basin, fires are typically concentrated in summer, and can be responsible of huge damages and large burned areas, particularly in correspondence of extreme weather conditions (dry fuels, strong winds, low relative humidity). In this study, we analyzed the recent dynamics of forest fires in *Quercus suber* stands in Sardinia (Italy), Corsica (France), and Catalonia (Spain) for the period 2003-2015. The analysis was carried out by combining forest data and historic fire perimeters, which were harmonized to allow comparisons among the study areas. On the whole, the study areas are characterized by about 260,000 ha of *Quercus suber* forests, which corresponds to about 18% of the European cork oak area. Approximately 21,000 ha of cork oak stands were affected by fires in the period 2003-2015: Sardinia accounted for about 60% of the *Quercus suber* stands burned in the study areas. A limited number of large fires was responsible of the most of the area burned in *Quercus suber* forests. Overall, the study highlighted a number of specific spatial and temporal trends of the fire issue on *Quercus suber* stands for the fire-prone Mediterranean areas under investigation.

Keywords: forest fires; cork oak; Mediterranean areas; fire management; forest management

TOWARDS AN INTEGRATIVE FIRE MANAGEMENT IN *QUERCUS SUBER L.* FORESTS IN NE SPAIN

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We studied fire effects in *Quercus suber L* in NE Spain after two wildland fires in 1986 and 2006 (under a 20-year fire recurrence). In this fire recurrence, species present resprouting as a key response to this disturbance. The development of a thick bark, that performs a thermal insulation, is a remarkable adaptation to wildland fires. Sampling was performed in 2012 in an area that offered different levels of fire behavior (i.e., low intensity and high intensity as reported by forest firefighters). Trees with previous, major fire scars were rejected since they did not allow us to infer the fire effect from the 2006 fire properly. 245 individuals were classified into three groups: “dead”, “BB” (lost the crown foliage but resprouting from basal buds); and “KC” (those keeping crown foliage because either not very much damaged by fire or able to sprout from most branches; i.e., stem buds). Results show that, under low intensity fires (surface fire), tree mortality is zero for trees in diameter classes (DC) above 15cm and 16% in the DC=5 & 10cm. Additionally, more than 60% in these classes (DC=5 & 10cm) do resprout from stem buds (very fast crown recovery), 93% in DC=15, and 100% in DC=20 and over. Under high intensity (crown fire), the damage is more evident and mortalities are 79% (DC=5cm), 32% (DC=10), and 8.6% (all above CD=10). The thinner individuals (DC=5cm) were mostly unable to resprout from stem buds (only 6.9% did so), although resprouted from basal buds (13.8%). Resprouting from the crown (stem buds) increased as DC increased. The effect of surface fires is minor in productive classes (i.e., CD>20cm) when addressing survival, although bark damages imply an economic loss. Therefore, a managed understory (i.e., low fuel load) has limited or zero tree mortality under an eventual fire. When high-intensity fires, and higher fire recurrence, the oak presence will tend to disappear due to the mortality of oak juveniles (small DCs), being replaced by a scrubland.

Keywords: *Quercus suber L.*, fire, resprouting, mortality, Spain

ORAL PRESENTATION

Session 3: *Multifunctionality of cork oak systems, biodiversity, climate change mitigation and landscape/ecosystem services*



MEDITERRANEAN FOREST: THE INEVITABILITY OF THE MULTIFUNCTIONALITY

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This article starts for making an edafo-climatic and cultural characterization of the Mediterranean environment that correlated with the characterization of the Mediterranean forest make a first conclusion: the inevitability of summer fires as natural evolution of these ecosystems.

The intervention of the Man in these environments was focused in the control of the main natural fuel that is the arbustive flora (shrubs), what could be done by mechanic ways (practicising of agriculture systems) or through biological form (using silvopastoral systems) and lead to the evolution of the Mediterranean forest producer as a farmer specialized in the integration of agro-silvo-pastoral systems, which as been assumed to call multifunctionality.

In definitive one concludes that each Mediterranean region became specialized in an agro-silvo-pastoral system, involving distinct vegetal and animal subsystems, but always with the common denominator of the high level of biodiversity and efficient integration of the diverse subsystems of production, providing environmental services. Presenting generally a proper identification, they are also recognized as sustainable models of technique, environmental and economic approach.

Keywords: agro-silvo-pastoralism, multifunctionality, environmental services.

MIXED TREE FARMING PLANTATION WITH CORK OAK IN TUSCANY GROSSETO PROVINCE

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Cork oak plantations in agricultural land are common in Mediterranean region. Traditionally pure plantations have been realized adopting a square design with 3-4 m distance among trees. These plantations have high management costs and higher pests and diseases sensitivity. During the 90', the farmland covered by these plantations was increased under the support of 2080/92 EU Regulation. Experimental plantations have been realized in Grosseto Tuscany with the aim to reduce management costs, pest and disease risks, and to realize new income differentiation and improve environment and biodiversity. Cork oaks have so been planted with a wider spacing (8-10 m) and intercropped with other tree species and shrubs, including also N-fixing species.

Different experimental thesis were compared. Pure cork oak plot; have been compared to mixed plots: cypress and N-fixing shrubs; cypress cedar and nurse trees, shrubs and other intercrops' types to improve wood and no wood productions.

In another mixed plantation, cork oak was intercropped with wild pear and Turkey oak to obtain cork, fuel-wood and valuable timber. The results of the monitoring have shown that cork oak mixed plantations have better sanitary conditions and higher productivity performances than the pure one. In particular the higher growth rate has been obtained in the mixture with cypress and N-fixing species, while the intercropping with Turkey oak resulted interesting for an early incomes due to fuel-wood production.

Mixed plantations have showed how the use of appropriate intercropping can be an interesting alternative to cork oak monoculture, reducing management costs and improving the growth rate, stem shape, pest and diseases resistance, early incomes, quality of environment and landscape. Cork oak in mixture seems to be more resilient, showing better sanitary condition than in monoculture. That is interesting considering the species susceptibility and the climate change challenges in the Mediterranean Region.

Keywords: cork oak, mixed plantation, N-fixing trees, landscape

CLIMATE CHANGE INFLUENCES ON ANNUAL CORK GROWTH AND QUALITY

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Since the last century, the global surface temperature has increased between 0.5 and 2 °C and future predictions show further increases linked with reductions or shifts of precipitation. In some regions, these occurrences are determining severe water deficits and a general climatic unpredictability. In the Mediterranean region, exacerbated drought conditions and an increase in frequency of extreme events are currently observed. Cork oak (*Quercus suber* L.) is widely spread in the Western Mediterranean area and its ecological and economic importance is well known. However, severe concerns exist on the resilience capacity of the related ecosystems. In the current global change it is fundamental to protect and conserve the biodiversity of this species, especially by identifying adaptive traits and highlighting adaptive strategies that the species is able to display. In particular, this study aims i) to study the inter and intra-population variability of annual cork growth rate in relation to climatic anomalies and ii) to identify possible adaptive traits in order to drive strategic breeding programmes to favour species adaptation. Annual variations of cork ring growth were analyzed in relation to main climatic drivers (temperature and precipitations) from 90 cork oak individuals from three different populations in Sardinia (Fiorentini, M. Olia, Limbara Sud). For each population 30 cork plates (10 x 10 cm) were collected during the stripping of mature cork oaks. The plants were randomly selected from three sub-areas along the altitudinal gradient covered by the populations. For each sample total bark thickness was measured, rings were counted and cross-dating was carried out. The mean annual radial growth was measured and correlated with climate conditions and carbon isotope composition of the rings. This allowed to assess the influence of the main climatic factors on the pattern of ring growth. Furthermore, the climatic effects on cork quality were investigated.

Keywords: *Quercus suber*, adaptive traits, climate change, carbon isotope composition, cork quality

BIOMASS AND ALLOMETRY OF CORK OAK TREES GROWING UNDER DIFFERENT LAND USES IN SILVO-PASTORAL ECOSYSTEMS

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Cork oak (*Quercus suber* L.) trees are an important component of different land use types (LUT) in the silvo-pastoral ecosystems of northeastern Sardinia. Land use types differ in the density of cork oak and thus in the cork oak contribution to the ecosystem carbon budget. Differences in tree density also affect the allometry of the cork oaks and the cork productivity per tree and land unit. Quantifying biomass and modeling tree allometry is important to assess the ecosystem services provided by these trees in each LUT. This study focuses in three LUT: woodlands (W), wooded grasslands (WG), and open grasslands (OG). Four sites were selected with three sites having all three LUT and one site having only W. Systematic sampling with fixed-area plots was conducted in the summers of 2015 and 2016. In each plot, all trees above 5 cm in diameter at breast height (dbh) were measured. The tree attributes dbh, total tree height (HT), crown diameter (CD), debarking height, forking height, and bark width at several tree heights were measured. Above ground biomass (AGB) per tree and per hectare were estimated using published allometric equations. An analysis of variance was conducted to test whether AGB in cork oak trees differ by LUT. Linear and nonlinear mixed effects models were used to model the following allometric relations: HT-dbh, CD-dbh, and crown area-dbh. Models predicting bark volume were developed using different predictor variables. AGB in cork oaks in the OG was significantly lower than the AGB in the W and WG (mean AGB values of 3 t/ha, 49 t/ha and 26 t/ha respectively; $\alpha=0.05$), whereas the AGB in W and WG was not statistically different due to high spatial variability in AGB in the W. Allometric models had a good fit with root mean square values of approximately 25% of the mean of the predicted variable. These models provide reliable estimates in areas similar to those sampled and will allow estimating the contribution of the tree component in the carbon budget of the studied silvo-pastoral systems.

Keywords: cork oak, biomass, allometric equations, bark volume, height-diameter

CORK OAKS IN THE RURAL LANDSCAPE OF SARDINIA

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Rural landscape classification in Europe has been carried out in several countries using different approaches often linked to landscape and environmental strategies. In Italy, landscape classification has been envisaged at national level and implemented at regional level. The Autonomous Region of Sardinia (RAS) has developed a landscape plan since 2006. As a follow up, a research for RAS on the rural landscape of the entire island has been carried out and presented here.

Many rural landscapes of Sardinia are characterised by cork trees, which are around 80% of the surface of Italian cork oak forests. Most of them are concentrated in upper Gallura, land of the Sardinian cork industry. Cork oak landscapes of Sardinia show multifunctional systems with relevant environmental, economic and social value. Similarly to other Mediterranean landscapes, like the Portuguese *montado*, the Spanish *dehesa* and the Moroccan *azaghar*, they are agroforestry ecosystems based on cork oak trees on top of fall-winter grasses for cattle and sheep. Used primarily for cork trees and grazing, they produce a variety of products including wild game, mushrooms, honey and firewood, with quality cork, beef and sheep milk for pecorino cheese. Extending from privately-owned to public land, from limited shrub vegetation to vast forests, they represent ancient cultural landscapes with high natural and cultural values which require a sustainable management of multifunctional systems.

The study has outlined the features of Sardinian rural areas, where agriculture and pastoralism are the main activities linked to a traditional culture still in use, and where the cork oak landscape has a unique multifunctional character with high biocultural diversity. The methodological framework of the rural landscape classification of Sardinia, employing landscape units and types, and focussing on cork oak systems, has been illustrated with the first outcomes.

Key words: landscape classification, cork oak landscape, rural landscape, Sardinian environment

MODELLING GOODS AND SERVICES FROM CORK OAK FORESTS

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Forest ecosystems provide multiple essential ecosystem services (ES) for ecological and human well-being. In forest management, understanding of the services and functions distribution, interactions and assessing the economic value of forest ES represent an important future challenge to balancing trade-offs among them. In this study we consider three ES related to cork oak forest management: (i) carbon storage and sequestration, (ii) water yield, and (iii) cork production. We used the InVEST (Integrated Valuation of Environmental Services and Tradeoffs) model to compare current forest management (business as usual) with alternative management options over about 2,300 ha of cork oaks forests owned by Sardinia Region (Italy) and managed by the public Forestas Agency. Taking into account four carbon pools (above ground biomass, below ground biomass, dead organic matter, soil organic carbon), the current carbon stock value of the considered cork oak forests is estimated in about € 15 millions. Regarding the water yield assessment, we have considered two destinations, namely domestic and agricultural: a total of more than 120,000 m³ of water yield was reached. Finally, the number of stems, the period between two cork extractions, and the presence of pasture were used as factors affecting cork production. This approach, applied for the first time worldwide in cork oak forests, appears to be feasible and useful to support forest management and planning strategies in environmental contexts with similar characteristics.

Keywords: Spatial Decision Support System, InVEST model, carbon storage and sequestration, water yield, cork production.

CARBON BALANCE ESTIMATION IN CORK OAK WOODLANDS COMPARED TO LAND USE ALTERNATIVES

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In 2005, 11% of anthropogenic greenhouse gases emissions (GHG) were originated from agricultural activities and this value is expected to increase in the future. With European Union's legislation supporting and promoting the conversion of land into low-carbon-integrated agriculture, new opportunities arise for the implementation of this type of land use in Europe. In Portugal, cork oak woodlands are well represented by the *Montado*, that combines low density cork oak trees (*Quercus suber* L), with pastoral and/or cropping activities. The systems currently occupies an area of 715,922 ha partially with an extra suitable area of implementation of around 353,000 ha. Considering EU support and the capacity of agroforestry systems to act as a low-carbon with productive agriculture, the objective of this study is to compare the potential capacity of the cork oak woodlands to mitigate GHG emissions by quantifying the net carbon balance of activities in comparison to two representative land-use alternatives occurring in the same area: cork oak forestry and conventional wheat monoculture. The net carbon balance estimation focused on the difference between the amount of GHG emissions with Global Warming Potential (GWP) emitted by field operations and the amount of carbon the system is able to sequester aboveground (also by tree roots) estimated using a process-based model suitable for agroforestry systems called Yield-SAFE. Preliminary modeling results support the EU policies promoting the implementation of agroforestry systems in Europe. Even if the capacity of the agroforestry systems to sequester carbon is not as high as in forestry systems, the cork oak woodlands presents a similar capacity of carbon sequestration while offering: 1) a wider set of direct products such as wheat, cork, meat and wood, 2) a reduction of the higher amount of GHG emissions associated to mono-cropping while maintaining partially the provision of food and 3) other indirect environmental benefits associated to agroforestry practices.

Keywords: greenhouse gas emissions, agroforestry, Montado, carbon sequestration.

ORAL PRESENTATION

Session 4: *History, economics and policy, social perception
and communication, certification*



A RETROSPECTION OF CORK OAK (*Q. SUBER* L.) CULTIVATION IN BULGARIA

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First cork oak (*Q. suber* L.) experimental plantations have been established at the Southwestern part of the country and along the Southern 'Black sea' coast in 1954. The introduction activity has been developed in three directions, namely towards establishment of three types of plantations: introductory (experimental), experimentally-productional and productional, with plantations being established in Southwestern Bulgaria, Eastern Rhodope Mountains and along the "Black sea" coast. For 34-year period of time 1254 ha cork oak plantations in total have been established, from which 28.3 ha experimental, 12.9 ha experimentally-productional and 1212.8ha productional ones. Plantations have been situated in altitudinal range from 100 to 550m above the sea level. Acorns from Georgia (for experimental plantations) as well as from Spain and with local origin (for the last two types of plantations) have been used as reproductive material. The preferred method of experimental plantation establishment has been sowing of acorns (2-3) in nests within plots (1 x 1m) on either areas void of woody vegetation or after occurred reconstruction activity. Both experimentally-productional and productional plantations have been established in plots on preliminary prepared terraces. All plantations have been established dominantly at 5 x 5m density and at 6 x 6m in rare occasions. The first studies on the cork productivity of the local plantations started in 1969 and the real activity on commercial use of cork oak plantations was initiated in 2000.

Keywords: History, introduction, non-native tree species, plantations, *Q. suber* L.

CORK OAK CERTIFICATION IN THE MEDITERRANEAN BASIN: STATE OF THE ART AND MARKET TRENDS

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In the Mediterranean cork oak forest management could be reinforced through enhanced marketing efforts to promote the use of products deriving from responsible management. Among the most powerful communication and marketing tools, certification of well managed forest has an increasing role. The paper presents a state of the art of cork oak forest management and chain of custody certifications in the Mediterranean region: trends in certified areas, number of certificates of forest management and chain of custody, by countries. Secondary sources of information (online databases, books and articles) and interviews with sector operators have been used to create the dataset for a quantitative and qualitative analysis on oak forest management and chain of custody certifications and for the evaluation of cork oak certification strengths and weaknesses in promoting the use of raw material of responsible origin.

In the Mediterranean region certified cork oak forests covers about 517 000 ha (the 21% of the worldwide cork oak forests). Portugal, Spain and Italy are in order of importance the only FSC certified producer countries (FSC, 2016): Portugal covers alone the 70% of the FSC certified cork oak production. The FSC certified cork is sold and processed in 23 different countries. In particular, Germany, China, Portugal, Spain and USA are the top five countries for the numbers of Chain of Custody certification released worldwide (covering more than 60%). Several studies confirm the positive impacts of FSC certification at environmental level. Sustainable management practices are responsible for the implementation of specific recovering species programs (Dias *et al.*, 2013), areas important for the conservation of biodiversity (Dias *et al.*, 2016) and ecosystem services (Bugalho *et al.* 2016). An increasing importance is given to socio-economic benefits of certification: the connection between the implementation of conservation mechanisms through financial incentives (Bugalho *et al.* 2014), such as the payments for ecosystem services, has been identified as a potential tool to promote sustainable forest management initiatives while increasing benefits at local level (FSC Spain, 2016).

Keywords: certification, cork, market trends, forest management, chain of custody.

PEFC CERTIFICATION, SUSTAINABLE CORK PRODUCTION WITH MARKETING APPEAL

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The majority of today's global natural cork production is based in the Mediterranean region, principally in southern Portugal, Spain, France, Italy and North Africa. Some twelve billion natural cork seals are produced each year which if joined end to end would circumnavigate the world nearly eleven times over.

If managed appropriately, cork production is sustainable. Traditional production of natural cork is an environmentally sound process which supports the preservation of grassland forests, Mediterranean biodiversity, small scale agriculture, rural livelihoods, and fast-disappearing cultural traditions.

Today the Cork-oak PEFC certified forests count of 96,000 ha in Spain and Portugal out of 2,6 Million hectares; Portugal is the first cork-producing country (54%), followed by Spain (26%) and other countries (Italy has 3% share). In Italy there are not PEFC certified cork-oak forest.

Since cork is being used for every purpose (it is a very resistant waterproof material used for flooring, walls, furniture, tableware, clothing and accessories, wine stopper, even isolation of NASA space shuttles), industry is realizing that is useful for marketing purposes to communicate that cork is eco-friendly, if forest management is sustainable.

Since certified products are increasingly valued in the world market, particularly those which demonstrate environmental responsibility, PEFC Italy has been working with PEFC Portugal, PEFC Spain and other partners to promote cork certification. This initiative looks at both ends of the supply chain, creating demand and awareness among wine producers and retailers about the benefits of using PEFC certified cork, and encouraging forest owners in Portugal, Spain, France and Italy to produce PEFC-certified cork.

Keywords: PEFC certification; SFM; CoC; marketing; supply chain

ORAL PRESENTATION

Session 5: *Cork supply chain technology, supply chain arrangements, markets and trade foresight, product and process innovation*



INNOVATIVE METHODOLOGY TO INCLUDE WEATHER EFFECTS IN A SYSTEM OF EQUATIONS TO PREDICT THE EVOLUTION OF INDIVIDUAL TREE MATURE CORK CALIBER OVER TIME

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Introduction: It has been shown that annual cork growth is influenced by weather, namely by precipitation. However, existing models to predict the evolution of individual tree mature cork caliber over time do not include climate variables. This presentation presents a new system of equations that predicts the evolution of cork caliber over time considering the impact of weather.

Materials and methods: Data available for model development were gathered in 32 permanent plots distributed across the area of cork oak distribution in Portugal and includes around 9000 annual cork measurements made in boiled cork samples taken in two consecutive cork extractions (two cork cycles). The model developed includes a system of equations that is initialized with data from a cork sample: i) a model to predict cork growth index (the accumulated growth in the first 8 years of complete growth) in the cycle that just finished (cgi_1); ii) a model to predict the cgi in the future cycle (cgi_2), taking the weather during the two cycles into account; iii) a model to predict annual cork growth considering the effect of weather; iv) a model to predict caliber from cgi_2 and cork age.

Results: The proposed system of equations allows to predict annual cork growth taking into account weather variables, namely precipitation. When included in a decision support tool such as the SUBER model, it allows simulating the impact of different precipitation scenarios in the cork growth and resulting cork caliber.

Conclusions: Precipitation is a significant variable when modeling cork growth and cork thickness. The new system of equations allows simulating different precipitation scenarios in the cork growth and resulting cork caliber.

Keywords: cork oak; growth model; cork growth; cork thickness; precipitation.

WEBCORKY – AN ONLINE DECISION SUPPORT TOOL TO DECIDE WHEN STAND DEBARKING SHOULD OCCUR

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Debarking is one of the most important operations in the management of cork oak stands (*Quercus suber* L.) and usually occurs in periods of 9 years, currently the legal minimum period. However, whether in even- or uneven-aged stands, the cork oak stands are characterized by a natural diversity between individuals, a common characteristic of biological individuals in a constant adaptation and survival to natural selection. Considering the stand as a whole with an intrinsic heterogeneity, debarking stands when cork has 9 years of age may not be the optimal age to debark, given that the cork thickness may evolve to classes of higher industrial calibre, with a non-linear added value. WebCorky is a tool that, based on a cork sampling planned to characterize the distribution of cork calibre and quality within the stand, projects the growth of the cork, while linking 1) cork quality and 2) cork prices, providing a net present value of the stand, enabling the manager to decide if the stand debarking should be delayed to increase its profitability.

The tool uses equations from Almeida et al. (2010) to project the cork growth given a stand sample, characterizing the current thickness and quality of the stand (inventory). A double entry table combining cork thickness and quality thresholds with industrial standards, and therefore cork prices, is linked to the cork growth of each tree, allowing to project the cork growth predicting the respective value per ha over time. The tool has been implemented in a web interface, using python 2.7 (www.python.org), the DOJO 1.10 JavaScript library (www.dojotoolkit.org), and Google[®] charts.

The tool is currently online (<http://home.isa.utl.pt/~joaopalma/modelos/webcorky/>), providing an interface with some examples (from real stands) and is currently under further development to reach the needs of forest managers associations that could use this tool to improve the inventory and reporting methodologies to deliver to forest managers.

Keywords: management, tool, industry, cork value

FEASIBILITY STUDY OF NEAR INFRARED SPECTROSCOPY TO DETECT YELLOW STAIN ON CORK GRANULATE

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The aim of this study was to evaluate the potential of near infrared spectroscopy (NIRS) to detect the anomaly known as yellow stain on cork granulate. Detect this anomaly is crucial to the cork granulate stopper industry, since it is associated to the presence of 2,4,6-trichloroanisole or TCA. This compound being reported as the main agent responsible to the cork off flavours.

Samples for the NIRS spectra were prepared by mixing in different proportions granulates of cork with highest visual quality and cork with yellow stain, obtaining 120 samples with different percentages of yellow stain (0, 5, 10, 15, 25, 35, 50 and 100%). Two spectra per sample were collected using Bruker MPA spectrophotometer and the partial least squares (PLS) method was used to obtain numerous equations.

The best equation was obtained by utilizing the Standard Normal Variate (SNV) as a spectrum pre-processing and only making use of one specific part of the near infrared spectral range: 9400-4250 cm^{-1} . This equation shows a coefficient of determination (R^2) of 99,42%, a root mean square error of cross validation (RMSECV) of 2,34%, and a residual prediction deviation (RPD) of 13,10.

This suggests that NIRS technology could be used for detecting the presence of yellow stain on cork granulate. Nevertheless, these results should be confirmed with new studies which cover a larger sample group before being introduced to the production lines of cork granulate stopper industries.

Keywords: Granulate, NIRS, yellow stain, TCA

THE CAPACITY OF CORK FOREST FOR THE RETROFITTING OF RESIDENTIAL BUILDING IN BARCELONA

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Building sector represents one of the most important challenges in the transition to a lower carbon economy promoted by the European Union; where obsoleted building stock retrofitting is considerate one possible improvement action. One of the most extended strategies is increasing thermal insulation level of building, so it is necessary to expand the knowledge about thermal insulation materials for retrofitting, especially from a Life Cycle approach. The majority of these materials have non-renewable origin, but there is a small group of insulation material from natural resources. One of these materials is the cork, which good environmental performance has been studied in previous research. However, to facilitate policy-makings the study of cork forest capacity is crucial to know the possibility of cork as thermal insulation material at the urban scale. The aim of this study is to: first, to define different retrofitting scenarios of the residential building stock in the metropolitan area in Barcelona. Second, to know the current and future possibilities of cork forest capacities for using cork insulation product as material in different retrofitting scenarios, considering sustainable criteria of cork forestry development. The methods include in this study are: current and future cork forest capacity, measure environmental implications between materials at the urban scale and define retrofit scenarios, using Geographical Information Systems. These methods were tested for a case study in Catalonia (Spain), calculating the cost of retrofit all the residential building stock in the metropolitan area in Barcelona according to Catalonia Cork Forest capacity.

Results indicate that first, the use of cork as thermal insulation material to retrofit residential buildings at an urban scale could reduce significantly environmental impacts; second, current cork forestry development has capacity to develop the building stock retrofit of the case study area in medium and long term scenarios, and third future stages could increase cork forest capacity, improving the results obtained at this research.

Keywords: residential building, retrofit, natural materials, thermal insulation, scenarios valuation

LIFE CYCLE ASSESSMENT OF THE USE OF NATURAL MATERIALS AS THERMAL INSULATION IN BUILDINGS. THE CASE OF THE WHITE AGGLOMERATED AND EXPANDED CORK BOARDS

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The building sector is one of Europe's main environmental challenges, accounting for more than 40% of the continent's energy consumption and environmental impacts and the thermal insulation materials will play an important role in this challenge. Besides, the most common fossil insulation materials, there are natural materials with good insulation properties, including cork. The main cork insulation products are: the white agglomerated cork board and the expanded cork boards.

This study aims to analyse these cork insulation products used in buildings by means of cradle-to-grave Life Cycle Assessment methodology, excluding the use phase. The specific objectives are also to analyse the environmental impact of the different insulation materials, identifying the most influential stages and to compare them with the most common insulation materials. Moreover, to assess the influence of different end-of-life scenarios in the emission of the biogenic carbon stored in the cork boards.

The results indicate that the white agglomerated cork boards generate higher environmental impacts because the higher quantity of raw cork to manufacture the same functional unit than the expanded cork board does. In both cases, the manufacturing stage is the most influential stage, especially in the board agglomeration and the cork trituration, due to the large quantities of electricity and energy used. Moreover, the comparison with the non-renewable insulation materials indicates higher impacts of cork products for the majority of the impact categories, especially the white agglomerated cork. The main reason is the low technological development of the cork board insulation manufacturing process. Therefore, it is necessary to implement improvements at different stages of the board's life cycle, to further cork's advantages in mitigating Global Warming Potential.

Keywords: Life cycle assessment, insulation materials, agglomerated cork, expanded cork, sustainable construction, building energy

POSTER

Session 1: *Ecology, ecophysiology, health and genetic resources*



CHARACTERIZATION AND PATHOGENICITY OF *GEOSMITHIA*
LANGDONII ASSOCIATED WITH *PLATYPUS CYLINDRUS* (COL.,
CURCULIONIDAE, PLATYPODINAE) ON CORK OAK IN
ALGERIA.

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In insect galleries, many fungi exist, often largely ignored and their biological roles are unknown. These include anamorphic fungi of the genus *Geosmithia* Pitt (Ascomycota: Hypocreales) which have recently been associated with 33 species of beetles and other subcortical insects.

The species *G. langdonii* was isolated from mycangia, intestines and wooden galleries of the pinhole borer *Platypus cylindrus* in Algeria (M'sila West Algeria) and identified based on morphological and molecular characteristics (rDNA).

The relationship of this species with *P. cylindrus* and pathogenic action on the cork oak trees is still poorly understood. In this study, we tested this action on cork oak seedlings one year old. Inoculation of seedlings by the fungus was carried out in the nursery with controlled temperature.

The results show that the species *G. langdonii* shows several signs of pathogenicity such as leaves necrosis, branches and leaves drying. The death of inoculated seedlings can occur in less than a month.

Keywords: *Geosmithia langdonii*, cork oak, *Platypus cylindrus*, pathogenicity, Algeria.

BIODIVERSITY OF STANDS COCKROACHES IN OAK FORESTS OF ALGERIAN NORTHEAST

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Forest cockroaches are species that feed on plant debris and actively participate in the leaves decomposition and the humus formation. The omnivorous diet allows them to accommodate all types of food and can be adapted to life in all environments (tropical, subtropical and temperate areas). In this work, we developed an inventory of faunal species of cockroaches encountered in forest environments Northeast-Algerian. We have chosen five different oak forests: the cork oak forest in Edough (Annaba), the zeen oak forest in Edough (Annaba), the cork oak forest in Mechrouha (Souk Ahras), the zeen oak forest in Mechrouha (Souk Ahras), and the cork oak forest in Berrahal (Annaba). We identified five species of forest cockroaches belonging to three different genera, *Loboptera*, *Ectobius* and *Phyllodromica*. The density of these insects is a function of the biotope; *Loboptera* and *Phyllodromica* species abound in cork oak forests of Berrahal region as *Ectobius* populations occupy the most mountainous forests (cork oak forests of Edough and Mechrouha).

Keywords: Inventory, Dictyoptera, forest cockroaches, cork oak, zeen oak.

ASSESSING THE RESPONSE OF GROUND-DWELLING BEETLES COMMUNITIES TO DIFFERENT LAND-USES IN MEDITERRANEAN CORK OAK SYSTEMS

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Studying of macroarthropods communities in different land-use systems may be widely useful in defining management strategies in Mediterranean forests, mainly due to their sensitivity to human impact. This aspect is really interesting in agroforestry systems, where resources shall be managed in terms of ecological and functional sustainability.

In our study, we assessed the response of beetles communities at low taxonomical resolution to different Mediterranean cork oak land-use systems. Spatial variation of dung-beetles communities was also analyzed because of their potential role as ecological indicators in grazed areas.

We selected twenty-two sites in the northern part of Sardinia (Italy) where beetles were sampled by using a total of 220 pitfall traps. In addition, in each site, a number of environmental variables related to cork oak woodlands structure and land use were measured.

During the entire sampling period a total of 4550 individuals belonging to 47 families of beetles were captured. Multivariate analysis performed on ground-dwelling beetles data showed a distinct separation in terms of assemblages between grazed and low-managed sites (stress value = 0.178). Environmental variables significant affecting beetles assemblages were the sheep grazing, the average diameter of cork oak trees, the altitude and the degree of shrubs cover. Further, constrained multivariate analysis indicated the significance of grazing, by both large ($F = 2.36$, $p = 0.03$) and small domestic herbivores ($F = 3.88$, $p < 0.01$), and altitude ($F = 3.54$, $p < 0.01$) as variables determining dung beetles assemblages. Our results support the reliability of ground-dwelling beetles as valuable tool both to detect environmental changes in Mediterranean cork oak woodlands and to define management strategies useful to increase the resilience of cork oak agroforestry systems under future global change scenarios.

Keywords: human impact, cork oak woodlands, bioindicators, beetles,

BIOLOGICAL CONTROL OF *CORAEBUS UNDATUS* TO FOSTER SUSTAINABLE FOREST MANAGEMENT OF CORK OAK FORESTS IN CATALONIA

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Catalan cork has a slower growth than in other regions and this gives it a higher density. A characteristic that makes Catalan cork highly appreciated to produce cork stoppers for ageing wines. However, more than 80% of the annual cork production in Catalonia does not fit in currently standards of quality to produce natural cork stoppers. Mainly (60%) because of the growing impact of shingles (*Coraebus undatus*) that obligates to destinate most of cork production to granulate causing dramatic economic losses.

The beetle is fostered by drier and warmer conditions caused by climate change. This phenomenon has a direct impact with the weakness of trees.

Life+SUBER Project – which main goal is to improve strength and resilience of cork oaks to face the main impacts of climate change - implements biorational control of shingles based on mass trapping by visual appealing and a volatile compounds formula. The project focuses on a comprehensive approach to control of the pest, thus mass trapping is combined with different forest treatments to enhance vitality of cork of stands, to increase visibility of the traps, and to improve the quality of the habitat for bird species potentially predators of the genera *Coraebus*.

In addition, a new project has been launched to capture living beetles to synthesize specific pheromones. Based on the results of this work, we are currently working on the creation of a Supra regional Group at the Spanish National Level (GO BioCork), to take a step forward and ensure the improvement and continuity of biorational treatments to control the pest that causes millionaire losses to the sector.

First results of demonstration activities will be presented.

Keywords: Forest management, Cork, climate change, *Coraebus*, biological control

THE ECOLOGY OF SOME CORK-OAK (*QUERCUS SUBER* L.) STANDS IN NW SICILY.

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The uneven presence of the cork oak (*Quercus suber* L.) within its distribution range seems to be affected not only by its climatic requirements but also by rather specific edaphic needs. In fact, most of the known populations throughout the Mediterranean area thrive on acidic soils deriving from metamorphic or volcanic rock outcrops. However, some Italian populations of this species behave as if they were independent on the chemical and physical characteristics of the substrate, e.g. growing on calcareous soils, which are considered less suitable. This is the case of some populations in central Italy (Latium) and NW Sicily (Trapani Mts. and Palermo Mts.). A multidisciplinary investigation carried out on Palermo Mts. allowed: 1) to update the knowledge on the distribution of *Q. suber* in NW Sicily; 2) to verify that those populations are autochthonous; 3) to analyze and describe the soils and the plant communities linked with cork oaks; 4) to detect the ecological factors which could explain their local adaptation to calcareous soils; 5) to show the ecological, structural and dynamic role played by this species within the natural vegetation of Palermo Mts. The local presence of *Q. suber* stands may depend on three (perhaps synergic) factors: 1) the high fire frequency, which indirectly favours *Q. suber* by biasing the progressive succession towards the most common patterns of woodland, i.e. *Q. ilex/Q. pubescens* s.l. mixed forests; 2) the peculiar biogeochemistry of local soils; 3) the erosion that intermixed different parent materials.

Keywords: soil chemistry, wild fire, vegetation science

POSTER

Session 2: *Forest monitoring and management, land and forest planning*



IMPLEMENTING ROW SAMPLING FOR INVENTORY IN LOCAL PLANNING OF YOUNG CORK OAK PLANTATIONS

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During the '90s, implementation of Regulation EEC No 2080/92 by "Regione Autonoma della Sardegna", was largely concentrated on promoting cork oak plantations on the marginal agricultural land. The Regulation provided financial aid allowing the farmers to take care of the plantation but, few years after cessation of the support, lack of cultural cares was already evident. This paper is stimulated by the willingness of a breeding farm in central Sardinia (NU) to enhance the productive function (in the medium and long term) of their cork oak plantation created under the Regulation in 1996. To address the request a detailed inventory has been conducted, as a basis for the management and monitoring plan (Piano Colturale Forestale). This paper documents the methodological approach adopted to perform the forest inventory, taking advantage of the regular plantation pattern (3x3 m spacing). It is technically feasible to identify and map tree alignments across the whole property. Such 'rows' represent the statistical target eliminating area estimation problems involved in classical plot-based approaches. Furthermore, with equivalent costs, rows allow to locate a greater number of sampling units covering a wider range of stand conditions, including plantation edges and observations concerning cultivation practices. The methodology is presented as a cost-effective and efficient way to inventory young cork oak plantations in the context of management improvement through planning.

Keywords: young cork oak plantations, local planning, row sampling, local inventory

SHAPING FUTURE FORESTRY FOR SUSTAINABLE COPPICE FORESTS IN SOUTHERN EUROPE

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Coppicing is a traditional way of forest management that has been adopted across Europe, particularly in Mediterranean countries. In the past, coppice forests were heavily exploited by growing populations and emerging industries. More recently, coppicing is undergoing a new interest because of its adaptability, contribution to biodiversity and its use as a source of renewable bioenergy (fire wood, traditionally). In addition, it provided a number of non wood forest goods (mushrooms, honey, cork, game, fodder, fruits, pharmaceutical and aromatic plants...) and ecosystem services (FGS), often underestimated. By contrast, coppice is barely considered in Sustainable Forest Management (SFM) scenarios.

In this context, the LIFE project FutureForCoppiceS (Shaping future forestry for sustainable coppices in southern Europe: the legacy of past management trials LIFE14 ENV/IT/000514) aims to demonstrate the sustainability of different approaches in coppice forest management (traditional coppicing, natural evolution, pro-active conversion by selective felling). Existing and new SFM indicators will be evaluated, by means of long-term monitoring trials established over the last fifty years, to verify the consistency of each management system.

The project, which started in 2014 and is still running, builds on existing management trials installed in the late 1960s, with nine sites and 45 plots. Sites cover three European Forest Types (EFTs): mountainous beech forest, thermophilous deciduous forest, broadleaved evergreen forest.

The research activity on consolidated and new SFM indicators carried out in the eleven plots located in southern Sardinia and belonging to broadleaved evergreen forest will be showed in order to highlight the value of different approaches in ensuring provision of FGS and to improve the knowledge basis for the development of future, SFM of coppice forests in Mediterranean countries.

Keywords: sustainable forest management, indicators, silviculture, forest, management, Sardinia

GERMINATION BEHAVIOUR OF LARGE AND SMALL CORK-OAK SEEDS UNDER DIFFERENT TREATMENTS

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Although the studies on the germination of *Quercus suber* (cork-oak) acorns are not new and there is a great deal of knowledge about their germination behaviour, this study has a particular interest due to the provenance of the seeds and the interaction of three factors: the size of the seed, the cutting of the scar and the substrate of growth. The place of provenance, Matinha de Queluz, is an isolated peri-urban *Quercus suber* forest of about 20 hectares, classified as an *in situ* Genetic Resource Population and a cork-oak pristine forest (habitat 9330) of which the bark (cork) was never stripped. The seeds were divided in two criteria, large and small acorns. Each half was sectioned on the scar area to have cutted and uncutted acorns. Sterilized sand and peat were used as growth substrates for germination. A cork-oak seed germination test with eight types of combined treatments was performed. All the seeds were placed in germination chambers at room temperature during one month, and the radicle protrusion was counted daily. A preliminary statistics in the germination of cork-oak acorns from Matinha de Queluz point out that the scar cutting treatment is beneficial for both large and small seeds. Sand substrate induces a higher rate of germination in small seeds. The results also show that size has no significant influence on germination rate. As trees have a fairly stable reproductive behaviour concerning the size of the acorns, it should not be a criteria in seed harvesting. In practice, acorn size selection leads to the elimination of a part of the seed-trees, inducing the reduction in the genetic variability of the new stands. Seed harvesting for afforestation shall aim safe levels of genetic variability for adaptation and good characteristics of the new stands. Therefore the selection shall be focused on the phenotypic/genotypic characteristics of a minimum number of seed-trees in spite of the size of the acorns.

Keywords: *Quercus suber*, cork-oak peri-urban forest, Genetic Resource Population, Genetic selection, Seed size selection.

DENDROCHRONOLOGICAL ANALYSIS OF CORK OAK (*Q. SUBER* L.) ADAPTATION IN SOUTHWESTERN BULGARIA

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First cork oak (*Q. suber* L.) experimental plantations have been established at Southwestern Bulgaria and along the Southern 'Black sea' coast during the mid of 60's. Nowadays the obtained results are controversial, with some of the plantations being lost, but many of them displaying good health.

The study was carried out in a cork oak plantation situated in the Southwestern part of the country. The aim was to assess the local adaptation as related to the dynamics of the radial increment indices.

Multifactorial regression analysis showed that the temperature-precipitation regime was the main growth factor (coefficient of determination, $R^2 > 50\%$). As an additional task a comparison of climatic conditions in this part of the country were compared with those in the native areal of the species. The analysis was based on Walter's climate diagrams. A risk assessment for cork oak decline as result from the ongoing climatic changes was carried out according to Manion's scheme following the concept that trees' diseases result from multiple interacting factors to be grouped into three categories: predisposing, inciting and contributing. Both precipitation and temperatures were thoroughly analyzed as the most important predisposing factors. The impact of the cork harvest was the inciting factor, which mostly deserved our consideration. Among the contributing stress factors, *Phytophthora* spp. pathogens were considered to be of key importance.

Keywords: Dendrochronology, local adaptation, oak decline, plantations, *Quercus suber* L.

POSTER

Session 3: *Multifunctionality of cork oak systems, biodiversity, climate change mitigation and landscape/ecosystem services*



MODELLING HOW PENTACHLOROPHENOL POLLUTION AFFECTS FUNGAL BIODIVERSITY IN CORK OAK FOREST SOILS

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Previous studies led to discovery of a PCP mitigation pathway used by belowground fungi in forest soils; its prevalence may be correlated with PCP atmospheric pollution and/or misuse (1).

Using simple experimental simulations (submerged cultivation) we have evaluated the community differential response during exposure to 38 µM of PCP compared to control conditions. At the 3rd, 5th, 7th and 10th day of exposure we analysed the extracellular and mycelial sub-fractions, characterising both PCP degradation by the community and its taxonomic diversity. Next Generation Sequencing of mycelial collected at the 3rd and the 10th day of incubation (corresponding to PCP degradation levels of X and 70%, respectively) showed that PCP exposure dramatically altered the taxonomic diversity of the community. Fungal biomass was higher in control conditions, but between the 7th and 10th day of exposure the growth rate surpassed that of the control, suggesting recovery when substantial PCP mitigation is reached. In both sub-fractions and for all time points, a diversity of PCP related metabolites, particularly of downstream products of its degradation pathway (1) was identified (UHPLC-HRMS), consistent with the mineralization of the biocide. Our experimental approach is successfully revealing that even sub-lethal concentrations of PCP led to specialisation events within the fungal community

Keywords: Fungal communities, pentachlorophenol, cork oak forests soils, metabolome

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LOCAL LANDSCAPE DYNAMICS IN A TRADITIONAL CORK-OAK AGRO-FOREST SYSTEM (SARDINIA)

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The *Alta Gallura* region contributed to the development of Italian cork industry that since the nineteenth century has driven the improvement of a multi-functional model based on the breeding of beef cattle into the cork oak forests.

The study case is a cork-oak agro-forest farm extended to 212 hectares, with a quantity of livestock close to 0.1 LU ha⁻¹. It were collected data from the farm registry (business records of the last 70 years) and by photo-interpretation of images related to 1955 (GAI), 1977 (CGR), 2006 (Terra Italy) and 2013 (AGEA). The current landscape types are:

a) ICOF (Intensive cork oak forest: 500÷600 trees ha⁻¹), in 2013 extended for 121 ha (57% of the farm surface). ICOF represents the major source of income by the cork production (5.8÷9.6 q ha⁻¹ per year). Until 1950, the invasive species (holm oak and arbutus overall) was removed and used for coal production.

b) SAV (Savanna: 50÷100 trees ha⁻¹), for 22 ha (10% of the area). It originated in the fifties because of the oak thinning aimed to the durum wheat cultivation, now disused.

c) MEDm (Mediterranean maquis) extended for 26 ha (12% of thse area). It is a transitional community vegetation formed following the 1983 wildfire and evolving to pre-forest shrubs with holm oaks.

e) HOC (Holm oak coppice), with 12 ha (6% of the area). It is another transitional vegetation community developed following the 1983 wildfire, evolving at long-term to the holm oak high forest.

f) PAS. Pastures, extended for 31 ha (15% of the area), It is localized in the valley floor, where are the traditional farm buildings (in *Gallura* named *stazzo*). Finally, the 49% of the surfaces has preserved the 1954. The major changes regard recolonization areas (+10%, taken from the ICOF) and pastures (+9%, taken from SAV). The evaluation at local level highlighted the richness of the landscape mosaic and its changes in space and time.,

Keywords: *Quercus suber*, rural landscape, land use changes, GIS, Gallura.

TREE SPECIES RICHNESS IN ITALIAN CORK OAK FORESTS

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Cork oak woods are considered as spots of biodiversity in the Mediterranean area, but past management strongly influenced the reduction of tree species richness. In the framework of a Ministry of Agricultural, Food and Forestry Policies-funded project (FAESI), we analyzed the data of 143 plots of cork oak forests, collected during the ground survey of the National Forest Inventory (INFC2005). In 55 plots the cork oak was the only tree species found, whereas in 50 plots and in the remaining 38, respectively, two or more tree species were found. Analyzing the differences in medians between the groups of plots with increasing number of tree species with a Kruskal-Wallis test, we found statistical significance for tree density, volume, annual increment, tree and shrub biomass. On the contrary, for other stand parameters (cork production, environmental factors, regeneration) differences were not significant.

The reduction of tree species in cork oak stands is the result of management practices which aim to maximize production functions of the ecosystem (cork, pasture, crops) by reducing other tree species as much as possible: in fact, traditionally, other woody species have been often considered as having a negative influence on cork quality or the management purposes of the land. On the other hand, our analysis underlines the capability, for cork oak, to grow mixed with other Mediterranean tree species (e.g., holm oak, downy oak, strawberry tree) in several different environmental conditions.

We discuss the ecological importance of maintaining tree species richness in cork oak woods in order to maintain ecosystem resilience and offer more options for landscape and forest management. Biotic (insects) and abiotic (fire) disturbances, which occur more frequently in recent years driven by extreme events and climate change, suggest to manage cork oak ecosystems for complexity, giving greater importance to tree and shrub species richness.

Keywords: cork oak ecosystem services, tree species richness, forest complexity, biodiversity.

FUNGAL COMMUNITIES ACT AS BUFFER AGAINST THE DISTURBANCE CAUSED BY PENTACHLOROPHENOL IN CORK OAK FOREST SOIL

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Our study aims to establish the prevalence of pentachlorophenol (PCP) – an atmospheric persistent pollutant presenting life-threatening toxicity - in the soils of Tunisian cork oak forests (1), and elucidate both significance and impact of fungal activity in its mitigation and dispersion. Fungi are key colonisers of soil but their functional role as a community in the mitigation of soil pollution remains unclear, especially of communities of asymptomatic fungi (*i.e.* neither pathogenic nor symbiotic). To lead discovery, we analysed soils from Tunisian cork oak forests, characterising PCP prevalence and the cultivable belowground fungal community, namely taxonomy and mitigation pathway.

Most strains within the fungal community (77 in total, predominantly penicillia) can substantially degrade PCP up to 19 µM, and >1/3 up to 38 µM. PCP exposure, generally, increased both richness and functional diversity of the community. The PCP-derived metabolomes (mass spectrometry based analyses) of the cultivable fungi and the fungal community allow the identification of an array of degradation intermediates and by-products, including several hydroquinone, resorcinol and catechol derivatives, either chlorinated or not. Some of these derivatives were found also in soil, reinforcing both the on-site contamination with PCP and the crucial role of, fungi during its degradation (1). Further analyses of the functioning of belowground fungal communities are ongoing to better understand microbial specialisation, events and/or shifts in functional biodiversity that may happen during the mitigation of the biocide.

Keywords: Fungal communities, pentachlorophenol, cork oak forest soil

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POSTER

Session 4: *History, economics and policy, social perception and communication, certification*



CORK OAK MANAGEMENT SUSTAINABILITY: INDICATORS FOR A CERTIFICATION PROTOTYPE

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The key feature of Sustainable Forest Management (SFM) is the maintenance of biodiversity, regeneration and vitality of forest ecosystems without compromising their ecological, economic and social functions. SFM is particularly important in managed forest ecosystems such as cork oak stands, where human influence is considerable. Nonetheless, cork oak forest management may be highly sustainable and a few cases of certification occur. Cork certification can increase the product price but the lack of information on suitable indicators and experiences on their applicability at the management level limit its adoption. In this study we tested a set of indicators of sustainable cork oak forest management in Sardinia (Italy). First, we defined a list of specific indicators derived from attributes collected during the conventional management planning process. Secondly, we selected threshold values consulting a panel of experts on cork forest management. Thirdly, we applied the set of proposed indicators and related thresholds to a database of 361 sample plots and 285 forest compartments, representing 2% of the Sardinian cork oak forests, to test its potential suitability. Results show that structural and biometrical attributes can be easily exploited as SFM indicators. This approach drastically reduces the SFM information needed for a forest to get certified. Also the indicator spatial scale proves to be relevant: indicators up-scaling from tree to plot and to compartment level can be applied to overcome the influence of small areas which are out of certification standard.

Keywords: Cork oak forest, Sustainable Forest Management, Certification, Forest management planning, indicators, Sardinia

RESULTS OF CORK OAK AFFORESTATION CARRIED OUT UNDER EEC 2080/92 REGULATION IN GALLURA (SARDINIA)

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The impact of the MacSharry reform of the CAP was mitigated by a series of "social security nets". Among them there were measures for the increase of afforestation and timber production: the EEC Reg. 2080/92. The higher contribution reserved in Sardinian subregulation to oak species has favoured the cork, both for new plantations and for forest improvements. After twenty years, at the end of EEC aid for the "loss of income", it is appropriate to draw a technical evaluation on the success of the Regulation. The study was conducted in Northeastern Sardinia (Gallura), where you can find most of the new plantations and where an earlier study was made after 5 years from the plantation coinciding with the suspension of aids for "cultural practices". The plantations were realized in former fields under crop, after deep ploughing with rows geometrically arranged in a 3x3 m distance. The analysis, which covered a sample of 25 plantations on 500 ha, has included the execution of sample plots and the management, through an interview, of a special form to the owners of the plantations. Interviews and surveys show:

- The plantations in 60% of cases undergo regular crop care, with removal of shrubs by mechanical processing of soil
- After 15 years it became necessary the geometric thinning of conifer and, sometimes, a selective thinning out of cork trees
- After 20 years we recorded the mortality of about 15% of cork trees, an average height of 3.7 m, and an overbark d_{130} of 9.1 cm.
- The greatest average increase was found in the pure plantation with 0.58 cm year⁻¹, while in the subsidiaries the value drops to 0.46 for intercropping to 25% and to 0.40 in those to 50%.
- The average unproductive period (interval between the planting and the debarking) was about 45 years ranging from 33 for the best and 57 for the worst.

Finally, the results seem to be moderately positive, even taking into account that the other species (cherry and walnut, in particular) used in the context of Regulation have provided disastrous results with very high mortality rates tied up, among other things, with the aridity of Mediterranean summer.

Keywords: EEC 2080/92 Reg., afforestation, growth performance, EU rural development plan.

THE CORK OAK FORESTS MANAGEMENT IN SICILY: CURRENT SITUATION AND POTENTIALITY

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The economic importance of cork forests is mainly attributable to the role of provisioning non-timber forest products that they have played and still play in the Mediterranean region. In Sicily, according to the latest regional forest inventory (IFRS, 2010), the surface covered by cork forests amounts to 14,732 ha; the 52.4% of this area is not affected by cultural practices, while in the 41.3% of cases productive cultural practices are adopted. In fact, the prevailing silvicultural system type is the peculiar one aimed at the cork production. The cultural abandonment of many cork oak stands threatens their survival because of the close link between the conservation of cork stands and its use for productive purposes. The cork oak pure or mixed stands, in fact, are the result of human action that eliminated or limited the number of other species in favour of the cork oak. Therefore it entails close relationships between production and conservation.

Objective of this study is to analyse and summarize the existing data on the evolution of distribution and silvicultural practices carried out in cork oak forests in Sicily. The analysis of the current situation suggests the action and intervention ways aimed to continue preserving this typical Mediterranean forest landscape. In fact, cork oak forests not only assume an economic and productive function, but also have a strong social, ecological and landscaping value. In this perspective, the management of cork oak forests in Sicily, certified by specific sustainability indicators and aimed at obtaining quality productions, should foster and allow a sustainable development of this system with a balance of ecological, economic and social benefits.

Keywords: *Quercus suber*, Landscape, suber

THE USE OF CORK IN ANTIQUITY: SOME ARCHAEOLOGICAL DATA IN SARDINIA

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In modern and contemporary Sardinia, the cork is an important economic resource and the *Q. suber* woodlands have a very specific role in rural landscapes and in traditional agroforest and silvopastoral systems consolidated over time.

In this paper, we report some archaeological data from Sardinian contexts useful to summarize the use of the cork and the cork oak in antiquity. This use has its roots in the prehistory of Sardinia Island. Many archaeological researches document that it was already used during the Nuragic period (Bronze Age). The cork was extracted and processed in order to obtain plates, foils, planks, shavings and it was shaped to create various artefacts, such as footwear, containers, boxes, cases, stoppers, etc. Cork wedges were also used in nuragic dry stonewalls as thermal insulating.

Until a few years ago and even today in some areas of the Island, people used to gather oak acorns to produce a flour and to prepare bread. The discovery of acorns in Sardinian archaeological contexts suggests that they were employed for foods even in the Nuragic period. Especially *Q. ilex* acorns were used, but probably where cork oak woodlands predominate even *Q. suber* acorns were used. We consider that some place names (toponyms) in different Sardinia territories, like *suelzu dulce* ("sweet cork oak") in Gallura areas, could be associate with food preparations and "sweet" might be referred to acorns of cork oaks.

Romans worked cork for making caps to close amphorae, often sealed with additional lime or pozzolan. Also in Sardinia, some Roman archaeological sites document the use of cork for containers and to close amphorae.

Plastic and multiple use of cork products and multi-functionality of trees, fostered by traditional silvicultural systems which have enhanced cork oak ecological potential instead of other Mediterranean forest species, may have contributed to spread *Q. suber* in Sardinia better than any other Mediterranean island.

Keywords: prehistory, history, archaeology, Sardinia, nuragic civilization.

ENVIRONMENTAL CHARACTERIZATION AND CORK OAK PRESENCE BY TOPONYMS IN SARDINIA: AN ETHNOECOLOGICAL APPROACH.

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Phyto-toponymy sources can represent a useful ethnoecological instrument to retrace environmental history of places, like conservative milestones of local memory and linguistic relicts. Plant names could help in investigating land use changes phenomena as well as local glossaries of traditional knowledge and uses of environmental resources by local communities.

This work analyzes cork oak toponyms in Sardinia aiming at (i) resuming the ecological gradient of environmental factors behind vernacular names of place, (ii) testing a methodology to evaluate if conservative meaning of plant names respects the potential vegetation of Cork Oak as dominant forest species and (iii) actual land use.

Toponyms database of Autonomous Region of Sardinia has been used as fundamental information for the study. Database place names come from several cartographic sources overlaying, gathering and merging records from different maps with vernacular names verified from historical cartography.

Results show that phyto-toponyms related to Cork Oak presence are distributed all over the island, from 0 up to 1,000, with highest record between 300-400 meters a.s.l. (17% of total), especially under lower meso-mediterranean - lower sub-humid (36%) and lower meso-mediterranean - upper dry (17%), both weak euoceanic bioclimatic conditions. The 42% of the toponyms falls in the two potential vegetation series for cork oak in Sardinia: *Violo dehnhardtii-Quercetum suberis* and *Galio scabri-Quercetum suberis*. Concerning actual land use cover, the toponyms are included in broadleaves forest (16%), Mediterranean maquis (14%), garrigue (8%) and in various agricultural land use classes.

Records have been also clusterized concerning mean value of spatial density/square km per each historical sub-region of Sardinia, landscape morpho-toponyms and vernacular roots, in order to explore and to identify common local uses and shared traditions in cork oak toponymy.

Keywords: *cultural landscape; vernacular names; Sardinia; Q. suber; ethnoecology;*

POSTER

Session 5: *Cork supply chain technology, supply chain arrangements, markets and trade foresight, product and process innovation*



THE SUBER MODEL, NOW WITH ADDED OPTIONS: SIMULATING DIFFERENT SILVICULTURAL SYSTEMS AND ASSOCIATED PRODUCTS AND SERVICES

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Most of cork oak stands have been historically managed as agroforestry systems, combining trees with annual cultures such as wheat, that have been gradually transformed into silvopastoral systems that combine the trees with pastures and grazing under the trees. However, several management systems can be found, from stands managed with the objective to optimize cork productions to stands for which the multifunctionality is the management objective. Landowners are quite dynamic, always trying to adapt management to new market opportunities and changing edaphoclimatic conditions. The decisions about tree density (evaluated by crown cover), how often cork must be extracted (cork debarking rotation) and stand regeneration method (silvicultural system) are not straightforward. In a changing world, management must be adaptive, it is difficult to provide “fixed” silvicultural guidelines. Instead, adaptive management based on the monitoring and revision of the objectives, combined with the use of decision support tools to help landowners to analyse the best way to change management to face new frontiers (climate change, new markets, etc) and/or owner decision must be used. Such tools can be used for long term optimization of the system (strategic planning). The SUBER model has been first developed in 1997 and, from then on, it has undergone several improvements. The objective of this presentation is to show the more recent improvements integrated within the SUBER model, namely the possibility to predict site productivity, to simulate different silvicultural systems and obtain the associated products and services to support the landowners’ decisions. Different thinning algorithms are now available, allowing for the simulation of even- and uneven-aged structures or for the conversion from even-aged structures to layered or uneven-aged structures.

Keywords: cork oak management, SUBER model, decision support tools, silvicultural systems, thinning algorithms

MONITORING RAW CORK TCA CONTENT IN SARDINIAN WOODLANDS

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The studies on stopper contamination by TCA have focused on manufacturing phase and on relations between the wine and the cork. Less numerous are the forest and environmental monitoring research useful to evaluate whether different management models of the cork stands may have an influence on the process. In Sardinia, critical levels of raw cork contamination were reached in the last decade in an increasing number of forests thus increasing the contribution of technical corks and micro-granulation on the overall industrial production. In addition, industries owners push their suppliers to limit the presence of undergrowth forest vegetation, lowering relative humidity inside the forest in order to contain the action of biotic agents such as *Armillaria*. The use of heavier machinery for the shrubs thinning leads to soil compaction, new vegetation destruction, loss of cork forest biodiversity favoring, inter alia, the lepidopteran defoliating pulses, but reducing the risk of fire. Global climate change may enhance the action of fungal agents in the formation of TCA in the raw material.

This study involved the collection of ten-year-old cork samples from six public cork oak forests (with a high and rich undergrowth) vs a private no-bushy (silvopastoral) woodland. The raw cork planks were immediately transformed into cylinders having the dimensions of the standard stoppers, and then used for the TCA determination in accordance with the ISO 20752 protocol (GC-MS). The results show a wide variability between both trees and forests, with values generally lower than a fixed threshold of attention in 4 ng L^{-1} , but with the presence of outliers plus variants trees that have content in TCA higher than 20 ng L^{-1} . The microclimate monitoring of the main cork oak woodlands of Central and Northern Sardinia (the seven years 2010-2016 versus the thirty years 1971-2000) highlights an increase in maximum air temperature of December up to 4°C and in mean temperature of April up to 3°C .

Keywords: cork taint, TCA, raw cork, shrubs thinning, forest monitoring and management

MONITORING OF TCA CONCENTRATION IN STOPPERS OBTAINED BY CORK OAK FROM DIFFERENT SARDINIAN AREAS

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A big quantity of cork oak stoppers obtained by raw materials of known origin were submitted to analysis for TCA (Tri-chlorine-anisole) content. Data collection was made possible through the traceability quality system of the F.lli Molinas Company, sited in Calangianus, who friendly supplied stoppers obtained by cork collected during 2011 until 2014 years, in 17 different Sardinian areas.

A spatial and temporal distribution analysis of TCA biosynthesis phenomenon in the cork, through the use of both analytical data of sensory type and other instrumental determinations, was performed. By means of the sensory analysis, following the methodology of ISO 20752/2007 (E), it was determined the number of TCA-positive stoppers released and the percentage of caps with different defects. In each batch of caps, different scents have been identified: corked taste, mold, abnormal odor and doubt. The processed data from sensory analysis were broken down by geographic distribution and related to the instrumental determinations.

The chromatographic instrumental analysis showed a variation of very low concentrations of TCA, as regards the four years of observation and for the lots considered. However, the threshold of sensitivity for the corked flavor (4-6 nL) was frequently overcome. The ultimate goal of the research was to not only verify the existence of correlation between the results of sensory analysis on the different cork matches and TCA content but also highlight possible relationships between the experimental data and some eco-physiological variables. Among others, average temperature (minimum and maximum), average annual pluviometry, referring to the decade of the cork plank development were tested for the correlation with TCA content.

Keywords: Tri-chloro-anisole, stopper taste, sensory analysis

Essential Dictionary of cork and cork oak³

English	Italiano	Português
Agglomerated cork	Agglomerato di sughero	Aglomerados de cortiça
Bark	Plancia grezza	Prancha de cortiça crua
Champagne stoppers	Tappo tecnico per champagne	Rolha de champanhe
Colmated natural cork stopper	Tappo in sughero naturale colmatato	Rolha natural colmatada
Cork oak forest	Sughereta	Sobreiral
Cork oak savanna	Pascolo arborato a sughera	Montado
Cork oak tree	Sughera	Sobreiro
Cork stopper	Tappo di sughero	Rolha
Cork stopper industry	Industria del sughero, sugherificio	Indústria rolheira
Disc	Disco o rondella	Disco
Extractor	Scorzino	Descortiçador
Granulate	Granina, granulato	Granulado
Harvesting	Decortica	Desboia / Descortiçamento
Lenticular channels	Lenticelle (canali lenticolari)	Canais lenticulares
Micro-granulated cork stopper	Tappo tecnico in microgranulato	Rolha técnica micro granulada
Natural cork stopper	Tappo monopezzo in sughero naturale	Rolha natural
Plank	Plancia preparata	Prancha
Pore	Poro	Poro
Prepared cork	Sughero preparato	Cortiça preparada
Raw cork	Sughero naturale o grezzo	Cortiça crua
Refugo	Macina	Refugo
Reproduction or secondary cork	Sughero gentile	Cortiça de reprodução ou segundeira
Scrap	Sfridi	Aparas
Strips	Bandelle	Traços
Technical cork stopper	Tappo tecnico	Rolha técnica
Virgin cork	Sugherone o sughero maschio	Cortiça virgem
Wedges	Zeppa o pedana	Calços
Yellow stain	Macchia gialla	Mancha amarela

³ The glossary has been developed by M. Cillara, E.Fernandez Paradela and W. Habbachi

Español	Français	العربية
Aglomerado de corcho	Liège aggloméré	الفلين المكثل
Planchas de corcho/Pela del alcornoque	Écorce	القشرة / اللحاء
Tapón para champán	Bouchons de Champagne	سدادات قوارير الشامبانيا
Tapón de corcho natural colmatado	Bouchon en liège naturel colmaté	سدادة الفلين الطبيعي المعالج
Alcornocal	Subéraie/ forêt de chêne liège	غابة البلوط / غابة السنديان الفليني
Dehesa	Pâturage de chêne-liège	مراعي أشجار الفلين
Alcornoque	Arbre de chêne-liège	شجرة السنديان الفليني
Tapón de corcho	Bouchon de liège	السدادات الفلينية
Industria del tapón de corcho	L'industrie des bouchons de liège	صناعة السدادات الفلينية
Disco	Disque	قرص
Corcheros o peladores	Extracteur	مستخلص / مستخرج
Granulado	Granulé	محبب / فتات
Descorche / saca del corcho	Récolte	جمع / جني / حصاد
Canales lenticulares	Les canaux lenticulaires	القنوات العدسية
Tapón de corcho micro granulado	Bouchon en liège micro-granulé	سدادات من الفلين المجروش أو بشكل حبيبات
Tapón de corcho natural	Bouchon en liège naturel	سدادات (غطاء) الفلين الطبيعي
Plancha de corcho preparado	Une planche	اللوحة
Poro	Un pore	مسام
Corcho preparado	Le liège préparé	الفلين المخضر
Corcho natural o crudo	Le liège brut	الفلين الخام
Residuos/restos	Les déchets	النفايات / الفتات الباقي
Corcho secundario	La reproduction ou le liège secondaire	إعادة الإنتاج أو الفلين الثانوي
Recortes	Les restes	البقايا
Tiras	Les bandes	أشرطة
Tapón técnico	Technique d'isolation (ou de fermeture) avec le liège	تقنية العزل بالفلين
Corcho bornizo / corcho virgen	Liège vierge	الفلين البكر أو الفلين ذكر
Cepa o zapata	Les cales	دعامة
Mancha amarilla	Tache jaune	بقعة صفراء

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